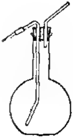
Science Education

for elementary school teachers



Photographs especially for this book by A. E. Woolley, Associate Professor of Art, State University College of Education, New Paltz, New York

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for elementary school teachers

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PREFACE

This book is designed to fill a gap in the science education preparation of elementary school teachers. During the past few years it has become more and more evident to the authors that their students, both pre-service and in-service teachers, have been unable to briog together what they have learned from the area of child development and the areas of science and curriculum. On the one hand, the students have studied child growth and development and the consequent learning theories which evolve from this information. On the other hand, they have had courses in science and in the science curriculum for the elementary school. But these courses generally have been compartmentalized both in the actual college situation and, more important, in the students' minds. From this book, prospective teachers as well as those already in the field can learn how to put learning theories into practice in the science classroom. The book is intended for use in undergraduate and graduate courses in Science Education in the Elementary School. It should also be very useful to workshop groups in school systems where plans are being made for

introducing or expanding the elementary school science program. The book brings together three important aspects of science education. In the first place, it presents the goals which may be established for elementary school science. Secondly, it outlines the science materials which can be used to reach these goals. Third, it expounds those aspects of child development which are of concern to the teacher of elementary school science. With these three factors as a base and using actual classroom descriptions, the book shows how elementary school science can be brought to life in a classroom and how science can be made an integral part of the entire elementary school curriculum. In agreement with the philosophy which holds that each child should receive his full share of attention and an opportunity for developing to his optimum potential, the book presents ideas for working with all children. In addition, it contains a special section on working with the academically able children who have so often been neglected in the past.

The photographic stories deserve a word of explanation. Although the photographs were taken especially for this book, they were not posed. They illustrate some of the ways in which teachers are actually teaching science to children. The photographs show what a person would see as he observed a class in action. Teaching and learning science is an active process; things are happening rapidly and all the time. The illustrations show this activity and movement. Three general situations are illustrated: a class as a whole working on a science unit; small groups studying some special phase of the class work; and individual children learning science. The photographs illustrate the kinds of science units which do not require specialists but can be taught by all elementary school teachers.

The authors want to thank all of the children and parents and all of the teachers who helped them both with the photographs and with the text. And A. E. Woolley, the photographer, certainly has

our thanks for the way in which he caught the spirit of the book in his pictures. Finally, thanks is due to the editorial staff of Allyn and Bacon, Inc., especially to Jean Swift and Wayne Barcomb, who saw this through with us from beginning to end.

HAROLD E. TANNENBAUM
NATHAN STILLMAN

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I SCIENCE IN OUR ELEMENTARY SCHOOLS

This is the age of the atom, the age of the man-made satellite, the age of antibiotics, artificial hormones, cybernetics, and automation. This is the age of science. Science has joined the "three R's" as the fourth cornerstone of the school curriculum. But what to teach? And how to teach it? These are the questions.

This book is written to help solve these problems. Reasons for teaching science will be discussed, but only after a workable definition of science has been established. We will examine children and determine some of the things that they need from their schools. We will examine schools and the demands that society has placed upon them. But mostly we will examine the teaching of elementary school science. There will be discussion of where a science program can lead; what can actually take place in a classroom during a science period; how the teacher can use his background to teach science; and how the teacher can expand his background in science.

A FRAMEWORK FOR SCIENCE TEACHING

Science teaching, like any other teaching, has to be done within a framework. First, the purposes of our schools need to be established. Then, we must determine what children can do and what they must do. And finally we must decide what science is and how it can fit into the curriculum of the school.

The business of the world is the curriculum of the school, with no holds barred. And science is everyone's business. What do you think about federal conservation policies? How about your local water supply—should it be fluoridized? Or what about the international control of atomic energy? These are everyone's problems. They make a difference to all of us. And these problems, together with a hundred others, must exist in this kind of society. The technology that we have brought into the world—for men have brought it into being—is going to continue to impose its problems upon us at the same time that it offers its benefits. But modern society has another characteristic. This is a democracy. All people are important. All people either do have, or can have, or should have a voice in the ways in which society's problems are solved. The decisions on these problems must be made. Either we, all of us, will make the decisions, or they will be made for us by a smaller and ultimately dictatorial minority.

It is not easy to make these kinds of decisions. It takes information. It takes objectivity. It takes profound thought. Most of all, it takes courage to act and behave democratically. So children have to be prepared for all of this. And the schools have been assigned the task of helping the children become participating citizens.

Most contemporary problems with which the citizen is concerned are interwoven with science. The water conservation

policies of the federal government involve everyone in a dozen different ways. The amount of food available, the cost of this food, the future of the nation's natural resources, the needs of farmers, the effective use of water for industry, transportation, power, and recreation, in addition to its use for agriculture, are all tied up in this question. Certain things are known. Some of our land should not be used for annual crop production. Because of the water situation, such use of this land can only cause it to be completely destroyed. This information has been provided by science. What is done with this information is outside the realm of science. But science is involved in these social problems.

Consider the problem of adding fluorides to a water supply. Many misstatements have been made, but the facts are easy to come by. Many reputable medical agencies advocate the addition of fluorine salts to water supplies. They advocate this on the basis of a series of tests and experiments which seem to them to show that the addition of this material to drinking water lessens the possibility of tooth decay and does no harm to the drinkers. This is the science. Other questions such as cost, private versus public addition of fluorine, government interference, and so on, also need consideration. But science can give some of the facts to help people make rational decisions about personal and social problems.

A DEFINITION OF SCIENCE

As an individual and as a citizen, each of us needs science. Most people use it, or at least claim to use it, regularly. But what is science? For one thing, it is an organized accumulation of factual information. For another, it is a series of generalizations based on these facts. It is, however, much more than this. Science is a way of thinking, a way of feeling, and, even more important, a way of behaving toward people, toward things, and toward ourselves.

It is true that science presents "the facts." The "science of astronomy" is the body of facts, systematically arranged so as to show the operation of general laws which have been developed from a continuous examination of the universe. The "science of geology" or the "science of physics" or any of the other "sciences" could be defined in a similar way. Having defined them thus, we still would not have a picture of science, and need to go further to get a complete idea of what science is.

The facts are only a part of science. Beyond them is an attitude toward fact finding and knowledge in general. We must want to know, to understand, to search for answers to the questions asked, and to search for these answers with as much objectivity as is humanly possible. We must have the courage to look at ourselves and at the world, and have the honesty to allow investigations to be full and free and open. We must have the vision to see beyond the limits of hypotheses and the humility to change preconceived positions when the evidence presented by the facts denies and negates them. Given this attitude, we can learn to use the rational techniques of thinking that have come to be associated with science. We can find and define problems. We can accumulate data which bear upon them. We can propound hypotheses. We can test the consequent deductions and alter or affirm original generalizations. And then we can go on with this rational examination of the world and of ourselves. A consideration of all these facets presents a more accurate picture of science today.

One thing should be made clear—science has definite limits. Science can give the facts; it can give the generalizations and theories based on these facts; it can give a way to look at and look for facts. But science cannot provide moral judgments. Science is not "good." Nor is it "bad." Science can only point direction for action and give guideposts for behavior. These are its limits. To expect more from science is to deceive one's self and to do a disservice to society.

THE TASK OF THE SCHOOL IN REGARD TO SCIENCE EDUCATION

Here then is the situation. We are faced with the problems of a modern, technical society. The solutions to these problems demand scientific information, scientific attitudes, and scientific behavior. All people need to participate in these solutions. So the schools have been given the assignment of helping people to understand the world in which they live and to make rational decisions about current problems. This gives the school a grave responsibility. If the people are going to make decisions on matters which concern atomic energy, then they should know something about it, about what it can do to them and for them. If they are going to make decisions about power and conservation and medicine and food resources, then they must have knowledge of these matters. What is studied is very important. The curriculum must include those things which are vital in this technical, industrial, democratic society.

Then there is the task of helping children develop attitudes towards the use of scientific information in the solution of social problems. As we said before, science includes the attitudes and behavior of people as much as it does a body of facts and generalizations. The school must assume a large share of the responsibility for developing these scientific attitudes and sponsoring this scientific behavior in citizens.

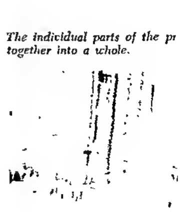
Finally, there is the task of helping children understand and fulfill themselves. The school needs to guide them so that they may become creative, rational, purposeful, and reflective so that they may establish personal principles and values. The school, and science education as it exists within the framework of the curriculum, must help children with these personal problems. We want children who not only understand facts, but who also behave in positive and creative and rational ways because of their education.

Citizens need to see the whole world as it is, as it was, and as it can be. And they need to act in such a manner as to ensure the well-being of all people. Society has assigned to the schools the task of helping develop such citizens. Teachers must take up the challenge.

Each child uses his hands to help build.

The necessary information is found careful reference work.

The individual parts of the pr together into a whole.



The teacher helps when needed.

There are always finishing touches to be added.

II DEVELOPMENTAL CONCEPTS AND SCIENCE TEACHING

To meet society's challenge, the teacher must solve the problem of what and how to teach children. There are many plans, many techniques for fostering learning in children. When faced with such a broad problem as this, it is well to look for fundamentals. It is axiomatic that the teacher who has a real understanding of child growth and development is more likely to be competent in guiding children in learning situations. Without an understanding of how children learn, without insight into the reactions which they have, or, in other words, without the ability to see children in relation to what is being taught, the teacher is not likely to have much success in his work. There is an old story which puts the matter very well. It tells of an incident early in the careers of both a teacher and a youngster while both were struggling with arithmetic, she to teach it and he to learn it. The teacher posed what she thought was a fine problem for the children. "If your mother had ten cookies and your brother was told to take two, how many would be left?"

The problem was easy. It was clearly stated. It led to the generalization that she wished to make. Nothing could go wrong, yet something did. The youngster listened skeptically to the question. The answer was obvious to him. "None," he said. The teacher was startled. "No. That's wrong. The answer is eight." With utter disgust came the boy's reply. "Teacher, maybe you know arithmetic, but you don't know my brother."

The teacher had lost sight of what children are really like and what that does to learning. She did not take into account the impact of cookies on children and the rivalry between siblings. Teachers who have a real understanding of the principles of child growth and development will be much more competent in guiding children in learning situations. As the teacher comes to understand the characteristics of the children with whom he works, he becomes more effective in his teaching. For example, an understanding of the concept of readiness and its implications for learning can make the difference between encouraging intellectual curiosity and stunting it. Similarly, the insight into various aspects of pupil behavior can result in more productive and efficient learning situations. If the teacher knows the kinds of things that can be expected, if he can anticipate children's actions and can plan for them, then the classroom becomes a place for guiding children's growth, and the teacher is able to use the inherent characteristics of children to help them grow.

It must be pointed out at once that the teacher is not a psychologist. Nor should he be. The teacher is engaged to help children achieve specific knowledge and skills which will serve both them and society in the present and in the future. The teacher teaches the children to read, to write, to do arithmetic, and to understand many things, not the least among them being science. To discount this function of teaching knowledge and skills would be completely unrealistic. Furthermore, without such knowledge children would not develop the healthy personalities

that are needed in today's world. So there really is no choice between teaching science and teaching Johnny. Rather, the teacher's task is teaching science to Johnny in such a way that he will be enabled to function more adequately and more creatively in the world in which he lives.

Therefore, the teacher needs to know much more than simply the developmental characteristics of elementary school children. What the teacher needs is an understanding of how the basic principles of child growth and development are applied in classroom situations. It is all very well to know that "growth" is the fundamental characteristic of all living things, that plants or animals, children or old people, students or teachers, doctors or lawyers, richmen or poormen all grow, and that when they stop growing they are dead. But what does this mean to a teacher? An understanding of children and of their patterns of development is significant in relation to its effect on the way a teacher works with his students. In other words, theories increase in value and gain significance in direct proportion to their applicability in real situations. Here are some basic concepts about child growth and development and their implications for science teaching.

INHERENT DRIVES

Inherent in all individuals is an impulse to grow. Being alive is almost synonymous with growing. Clearly, while an organism is alive, it is continually growing, replacing worn out cells with new ones, changing size, changing shape. This applies to all living things including humans. But human growth has additional dimensions. Not only does growth mean growth of bones and muscles. It also means growth of ideas and of feelings. It means getting bigger. But it also means developing a more adequate structure and the ability to function better, so that each human reaches toward self-realization. This force of growth is in con-

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tinuous operation, allowing the individual to become larger in size and, concurrently, giving him more adequate control over his environment, making it possible for him to change his ideas and his ways of doing things, allowing him to develop new feelings about his world and new modes of coping with it. How much this force will move the individual—how dynamic it will be—is directly related to the environment. One environment will encourage growth in the individual. Another will hinder his growth. No one could question the relationship that exists between adequate diet and sound physical growth. It is equally true that there are similar relationships between environmental factors and mental growth, although these factors are less obvious. None the less, these relationships must be found and put to sound use in teaching.

One essential factor about growth in humans is that there really are no different kinds of growth. Through custom, and through previous invalid theories, three kinds of growth have been noted—physical, mental, and emotional—with the implication that these are three distinct and different phenomena. In reality, these three factors, any one of which may stand out at a given stage of development, are only different aspects of the same single indivisible phenomenon, growth of the human being. They are interwoven and inseparable and must function as a whole. And since they are so interrelated, the environment in which the human lives has an impact on all of the aspects of his growth. A limited physical environment can stunt an individual's growth in all its aspects, in the mental and emotional as well as the physical aspects. Everything that is known about people and how they live and grow shows clearly that there is a unity of mind and emotion and body. What happens to his big toe affects what happens to his classwork and vice versa. The child is a whole being and he must be taught as a whole. The teacher has to accept the squirms of the ten-year-old along with his fine mind and enthusiasm for learning because all of these things make up the child, the whole child.

Just as an adequate diet is necessary for growth, so other ingredients are necessary for the healthy growth of the whole child. A few basic ones are security, an opportunity to use one's capacities, and a sense of achievement. Providing these factors in the child's environment facilitates his growth. Security is as good a starting place as any. Children need the security of acceptance. They need to feel welcome. They need the assurance of a home base. Then they can go on in their growth to explore and to develop and use their capacities. This trying, failing and trying again, this learning new skills and new ways of putting ideas and concepts together is also an inherent part of the individual's make-up. Given a secure base, a feeling of belonging and of being wanted, the child can satisfy his inherent desire and need to learn and to use his natural capacities. And with each new learning comes a sense of achievement and a pride in self which he can take back to his home base to make him more secure. But now home base has changed, because the individual has changed. It is a new home base in a wider world. Still, the way in which he *learns is the same. Starting out from the security* of an accepted place and a feeling of belonging, the learner goes on to develop his new capacities and to achieve new growths of all kinds. These, in turn, lead to further satisfactions and to further growths.

In the primary grades children exhibit a tremendous urge to grow mentally. They have an insatiable curiosity and are constantly involved in asking questions on a great variety of subjects. And the more they learn, the more they question. It would seem that this pattern should go on indefinitely. Intermediate and upper grade youngsters are expanding their powers of observation, and increasing their knowledge and skills. One would expect this expanded vision to bring on a flood of new, and wider, and deeper questions. But the questions frequently slow down. There are still questions, but not from all the children. The dangers of asking the "wrong" questions become too great. By high school there is usually a slow trickle of questions and, in college, the professor has come to expect a quiet closing of notebooks at the end of a

lecture and an embarrassing silence during the question period. What has happened to the impulse to grow and to learn? Apparently, for many students the environment of the school has not encouraged growth but, instead, has blocked it. Somewhere between the primary grades and the college class there is a break in the cycle of growth from security and belonging to exploration, then to a feeling of accomplishment and achievement, and thence to wider security and on to new growths. This break in the cycle, this lack of an environment conducive to growth has created a serious loss both to the individuals and to society.

Another factor stands out when one examines the growth of children. Each child has a different rate of growth and a different potential for maximum growth. One never questions the differing physical sizes of people. All are accepted, the big ones and small ones, the fat ones and thin ones. In like manner, individuals differ with regard to their emotional patterns. Who is to say that the quiet, retiring person is more or less desirable than the gregarious and out-going person? Similarly, it must be recognized that each person has a given potential for mental growth and development and that each child grows at his own rate.

If the concern of education is to foster optimum growth in each individual, then schools are failing. This has been known for a long time and there have been ever recurring examinations of curricula and of procedures. Many new curricula have been devised and new procedures are continually being introduced. But it is most important to recognize the fact that neither curricula nor procedures are the ends of education. They are merely the means to an end. What children are to learn and how they are to learn it must be determined by the influence that this material and these techniques have on the total growth of each child.

The problem, then, is to find those materials and to devise those techniques which will make an optimum contribution to fostering

the growth of children. The elementary school science program can provide an excellent opportunity for satisfying the basic needs of children, thus contributing to their desirable growth. Children have always shown great curiosity about their physical environment, principally because they have needed to deal with it. Survival has required that children develop certain simple understandings relating to things they must not eat, or must not touch, or must avoid. When the child enters school he already possesses a body of information with respect to his physical environment, even though it may be very primitive. Here then, is a base upon which further understandings of the world can be built. As children are guided into explorations of their expanding environment, they develop self-confidence. They grow more sure of themselves and of their relationships with the world around them. Natural phenomena, like thunder and lightning, or plants and animals, or mushrooms and snakes, no longer cause irrational fear. Instead, with proper teaching, there comes a respect for and a rational relationship with the environment. As children learn, they become able to use what they have learned in their relationships with others, especially with their parents. This does much to give youngsters a feeling of belonging and to increase their status both in the eyes of others and, more important, in their own eyes. The child needs to understand satellites and jets, antibiotics and radioactive elements not only so that he can make his own adjustment to the world, but also so that he can participate in his various social groups—his peers, his neighbors, his family. And through these contributions the child becomes a more secure member of these groups.

There is in the science material a further inherent value that must not be neglected. This material, more than any other curricular material, provides for the interests and needs of children of varying abilities. There is work, there are ideas, there are concepts for the slow ones, and there are equally challenging materials for the most capable, even for the gifted when such children are found

in the class. Furthermore, each of these groups, each child in fact, has a wider range of opportunities for exploration in science than in any other area. Each topic has many possible avenues of investigation which can be explored to a greater or lesser extent. Thus, there are plenty of experiences for all the children. Through a sound use of science materials children can attain greater self-realization. A well-taught science program can lead to maximum, well-rounded, and healthy growth for each child, regardless of his abilities.

READINESS

There is an optimum time for certain learnings. Directly derived from the concept of growth, and closely related to it, is the concept of readiness. Readiness means that growth exerts a definite influence on learning and, consequently, children can be introduced to new learnings either too early or too late for optimum growth to take place. Two factors are the determinants of readiness, the child's stage of development and his cultural milieu. Each of these needs consideration in the selection of appropriate materials for the curriculum and each should influence the techniques used in conducting a class. These factors have special implications for the science curriculum and can readily be taken into account in establishing it.

Take first the matter of biological readiness. For a first grader, the microscope would probably be a source of frustration. Quite aside from the difficulty of grasping the meaning of the microcosm, it is likely that his eyes could not focus on the field of a microscope. On the other hand, a long handled magnifying glass could open new vistas for his busy mind. A hand lens hanging next to a classroom aquarium can bring whole new worlds to the eyes of a six-year-old, and a lens taken along on a trip around the school grounds can afford many a new and exciting experience. Using the concept of biological readiness means introducing tools

which children can learn to use and facts and generalizations which they can assimilate.

But the child's stage of mental growth must also influence the science curriculum. A child in the primary grades who discovers with fascination the accidental rainbow cast by the acquarium is ready to explore other ways of making rainbows and to generalize on the conditions needed to create this phenomenon. But it is unlikely that he would be ready for a study of the differences between reflected and transmitted colors or a consideration of the *wave lengths of lights. Such facts* and *generalizations are too* abstract for a young child and are more appropriate for high school or even college. Yet each topic in science has within it generalizations which the child can understand and use at his various levels of maturity. There is material in the topic of "light" for the six-year-old, for the ten-year-old, for the high school junior, and for the college senior. The teacher introduces what the children in his group are capable of absorbing and using. The other side of the coin is also significant. Introducing ideas and activities too late in the growth of children can mean boredom, rejection, or even revolt. Trying to get eleven-year-olds excited about the ways in which animals and plants prepare for winter can be frustrating to the children and consequently to the teacher. And studying about what *magnets can* pick up and what they can't will pall even for the most patient children after they already have worked with magnets for three or more years. But since science topics lend themselves to presentation at various levels and in various ways, such situations need not arise.

Equally important in the operation of the concept of readiness is the cultural milieu of the children. A child raised in a rural environment, one who lives with animals and plants all the time and who knows through personal experience many of their characteristics, is likely to be ready for a study of such materials much sooner than his city cousin. And conversely, the city child is ready for a study of elevators, and subways, and rapid transit systems

sooner. Children from either environment can find stimulation in both studies, but choosing the appropriate materials at the right time for each group is essential. Even more significant is the factor of new forces in the culture. A fourth grader of a generation ago scarcely knew the word rocket except for the fireworks on July Fourth. But today, because information about successes and failures at Cape Canaveral and elsewhere are quickly disseminated through the media of television, radio, newspapers, and magazines, it is the rare child who has not either seen a rocket leave its launching pad or at least heard it described and seen pictures of it. What was too complex, too abstract, even exotic for the children of 1920 is commonplace and significant for today's children.

Readiness, then, is dependent on several variables and no simple formula can indicate when a child or a group of children are ready for specific learnings. Thus, the curriculum in elementary school science, while based on over-all science generalizations, must be adapted and adaptable to the child's degree of readiness both in terms of his capacity for understanding and in terms of his interests and needs. In other words, the science program must be diversified, the topics must range over the entire field of science, and the concepts and facts must be drawn from several sciences if they are necessary for the satisfaction of a given stage of growth. Furthermore, the selection of materials must be flexible so that it takes into account the child's stage of growth. This, however, is not too difficult because the generalizations of science, as has been noted, lend themselves to exploration at various depths and for varied maturities. This means that while a class of children is working on materials from a single generalization, they will not necessarily all be involved in identical activities. In fact, as a class works on problems derived from science materials, there will be many times when the work of different individual children in the class will range from profound studies of advanced materials to simple examinations of beginning concepts about those same materials.

But the most important aspect of the readiness concept indicates the interrelatedness of learning and readiness. It is perfectly true that meaningful learning cannot occur until the child is ready. But it is also true that each bit of learning that occurs, each new fact, idea, concept, generalization, or skill helps produce readiness for future learnings. The teacher does not sit around and wait for the children to "get ready" and then, when the time is finally ripe, teach the appropriate material. Rather, readiness can and must be brought on through the activities of the school. Watching and noting the daily weather conditions in the first grade is a part of the preparation for studying weather in the third, fourth, or fifth grade. And these studies are a prelude to the studies of meteorology which the children will do later in high school and college. Looked at from the other point of view, the teacher who is going to work on a new unit with his class must go back and review what the children have studied in related topics and must work to bring about a readiness for new learnings. It is through such reviewing and interrelating of new and old learnings that teachers bring about the sound use of the readiness theory.

TRANSFER OF LEARNING

There are conditions which favor the transfer of learnings from school situations to out-of-school situations. To ask why children go to school, to ask why a society spends a significant portion of its annual income on educating its children, is to ask the obvious. Children are sent to school to learn how to cope with things which they will meet in their lives outside of the classroom. In other words, it is hoped that the students will apply the skills, the methods, the ideas which they learn in class to the solution of problems which they encounter outside the classroom. This is certainly a prime assumption, if not *the* prime assumption, underlying all formal education. And it is in this light that the present emphasis on an expanded science curriculum for elementary schools must be viewed.

The question of transfer of learnings and the conditions which will favor optimum transfer are therefore of vital importance to every teacher. Certain things are known about transfer. For one thing, what is taught in the classroom is of great importance in determining how much transfer, if any, will take place. It was thought formerly that the function of school was to "exercise the mind." But all of the experiments which were carried out to test this hypothesis indicated no such relationship. Next, it was thought that transfer needed to be "item for item." But this too was unsound. In the first place, no one could teach all that needed to be taught. In the second place, much disagreement as to what needed to be taught prevented the establishment of satisfactory curricula. If children are to develop into adults who will be competent to meet the multitude of problems associated with daily living, education must be concerned with the applicability of school learning to the broader areas of the community, the nation, and the universe.

It is generally recognized that positive transfer of learning from one situation to another is not an automatic process. The acquisition of knowledge and skills per se does not assure that this knowledge and these skills will be appropriately applied to new situations. Yet the fact is that many courses and many school programs are looked upon as hurdles to be vaulted. Neither the students nor anyone else considers the transfer of the material of the course to real life situations. In such cases the course or topic becomes an end in itself. Transfer, in that kind of a situation, means transfer of learnings to tests and final examinations and not necessarily to out-of-school situations. But this negates the prime assumption of the function of the school. It would seem more likely, therefore, that if students are to demonstrate effective application of school learnings to real life problems, teachers must deliberately teach for transfer to life situations.

Transfer can occur more readily when students are helped to recognize that facts learned in one situation can be applied to other

situations. There are many examples of this kind of transfer. Why should anyone bother to learn mathematical information except because it can be useful in better understanding the environment and dealing with it? But this means that the teacher has a responsibility for making this richer understanding come into the lives of his students through mathematics. Or take the matter of science facts and their implications. Water freezes at about thirty-two degrees Fahrenheit. This means that we drain the water from a car radiator and replace it with anti-freeze as cold weather approaches. The fact requires action. Take another fact; the temperature at which water boils is dependent upon atmospheric pressure as well as heat. Water boils at one temperature in Chicago and another in Denver. This means that cooking and baking in Denver require quite different procedures than they do in Chicago. Only as facts are related, on the one hand, to what the learner already knows and, on the other hand, to the world that he has around him is effective transfer of factual information likely to take place.

The same is true in the case of principles and generalizations. Transfer can occur more readily when students are helped to recognize that the principles and generalizations they have learned in one situation can be applied to other situations. Again, the implications for teaching are very important. Not only must the principles and generalizations be taught, but the children must analyze similarities between the problems they have encountered in the classroom and the problems which exist in real life, the solutions of which are based on the principles studied. This means that many examples must be used and that the children have ample opportunities to investigate further applications of a principle in real life situations.

Consider a simple example. In 1783, a famous Swiss scientist, Daniel Bernoulli, wrote a book called *Hydrodynamica*. In it he established the major principle that when a fluid is made to move faster, the pressure which the fluid exerts is decreased. And con-

versely, when the fluid is made to move slowly, then the pressure which it can exert is increased. Stated more exactly, Bernoulli's principle becomes: The pressure and velocity of a fluid are inversely related. Now, obviously, in this form it has very little meaning for elementary school children. But consider for a moment. This is the principle used in the operation of carburetors for automobiles. Derived from this principle are jet pumps for lifting water, atomizers for spraying sore throats or for spraying perfume, spray guns for painting, many a water pistol, and also insect spray guns.

And, moreover, this principle accounts for the flight of airplanes. Air is a fluid (matter that flows). It flows over the wings of the airplane. A quick look at the wing of a plane shows that it has a special shape; the curve of the wing is such that there is more area on the top of the wing than on the bottom. Furthermore, there is a slight slant of the wing toward the back of the plane and toward the lower side. Now consider what happens when air is swept across such a surface. In the first place, on the upper side, because of the shape of the wing, the air must flow faster than it normally would. That means that the pressure on the top of the wing is reduced. But that is not all. Again the shape of the wing and its position on the plane make the air on the lower side flow more slowly and also deflect this lower air downward. Once more Bernoulli's principle comes into play. On the lower side of the wing, the pressure is increased. Thus, there is a decrease in pressure on the upper side of the wing and an increase in pressure on the lower side of the wing. Obviously, the resultant force is tremendous, enough so that planes weighing thousands of pounds can rise from the ground and stay in the air as long as the air around them is moved across their wings. How important it is that children learn the whole of a principle and the multitude of its applications!

However, it is quite important that children have enough varied examples of the applications of a principle so that they do not

confuse the examples with the principle itself. The salient thing is that each student see, to the best of his ability, what the fundamental principle is and how this principle is applied in a variety of situations to solve many problems. This is a slow, a hard process. But it is worth doing.

Transfer can occur more readily when students recognize that skills and techniques learned in one situation can be applied to other situations. Learning about weather forecasting and weather-map reading in school can be used for understanding weather maps and weather reports that appear in newspapers, or are heard over the radio, or are seen on television. But there are other less direct and less obvious relationships to be established. Techniques of measuring learned in a science lesson can be applied to all manner of tasks which need to be performed in life situations. Learning to read a thermometer can be useful later in dealing with clinical thermometers or cooking thermometers. Skills learned in the use of scientific instruments can be transferred to the use of any delicate instruments, such as cameras or binoculars.

And, most important of all, the ways of searching out, expressing, and solving problems through rational means can be transferred to many of life's problems *if* the principles of problem solving are taught and *if* there is a continuous and conscious effort to teach rational problem solving and to find applications of such problem-solving techniques to real life situations.

GROUP LEARNING

Some individual needs can be satisfied best as the child works with an entire class group. In recent years, the plea of many educators has been for attention to the individual and his needs. That this is important cannot be denied. Needs are different for each individual, patterns of growth and development are unique.

Each learns at his own rate and each learns what fits into his own background and set of experiences. Each individual also learns what he is likely to need in the immediate future. But these truisms have been distorted and false conclusions have been reached by many who argue that, except for the fantastic cost of such a venture, the best kind of education calls for an individual tutor for each child. Thus, from this point of view, maximum education comes as each child studies with his own private tutor. But this is an unsound interpretation of the theory of individual needs and individual progress. The fact of the matter is that even were it possible to have individual instruction for each child, there would be many occasions when group instruction would be more effective and more desirable. These situations are quite numerous with science instruction.

The value of the group as an educational tool lies in the fact that it is an additional way to develop and enhance the individual. The class is much more than merely an administrative device for conveniently classifying children. The class allows for group learning. Only in recent years have educators become fully aware of and concerned with the use of the group for teaching purposes. However, group learning is an old device. America's traditional "town meeting" was a good example of such a group. All the people of a community came together to solve mutual problems, to share ideas, to modify each other's view points. Employment of this technique in education allows teachers to use the interactions of children with their peers as a teaching device.

Development of the individual results as he interacts with his environment. In general, the broader the environment, the greater the development. But there are limits in the extent to which the individual's environment can be broadened. The key to the situation is the extent to which the individual can "interact" with an environment. Too large a group makes it impossible

for the individual to interact. Such an oversized group becomes merely a collection of individuals or a set of small and often unrelated sub-groups. No one yet knows what the "right" size group is. In fact, it seems likely that it varies from group to group depending on their purposes. But it is known that twenty-two to twenty-eight youngsters working together in a classroom group not only can learn without interfering with each other, they can be positively helpful to each other.

There are several ways in which children learn in a group situation. In the first place, problem solving can and often should be a group process. Under the leadership of the teacher, the children can pool their ideas on a problem. They bring to a problem information and ideas from many points of view and many angles, each contributing ideas from his own background. Then too there is the matter of drawing inferences from the material that has been presented. One child's ideas lead another child to see beyond what he would have seen had he not been in the group. Even those who only seem to listen and rarely actively contribute to the group have much more chance to learn as they are included in a group program. And, when it comes to the application of principles, to presenting examples of how the solution of the problem under consideration may be used in life situations, a well-knit group can be very effective in giving the individuals many ideas that they can use.

Over and over again science impinges on the social scene in various ways. Social questions of tremendous importance are raised by its activities and outcomes. Each citizen in America needs to establish values and to determine his position with regard to these questions. And an important function of the group is to help the individual examine, clarify, and establish these values. Different people have differing ideas and interpretations of how science should be used, and of what is "good" and what is "bad." Two important developments can come from group

examinations of these value judgments. First, children can bring their own sets of values into scrutiny. They can enlarge and expand their own points of view. Second, and equally important, children can learn how others think and feel. Even though they may not change their own viewpoints, they can learn to accept the fact that there are many ways of viewing a problem and its social consequence and that so long as these ways do not infringe upon the basic tenets of American democracy each person has a right to his viewpoint and the actions which derive from such a set of values.

Finally, there is the matter of communication. Fundamental to all human interaction is the business of communicating—talking, listening, reading, writing. Here, again, both science materials and group teaching can be effectively combined, and from the combination the individual children can profit greatly. Not only can they learn more science but they can learn to communicate with a much wider group in a classroom situation. They can learn to listen to many people, to weigh and evaluate what people say, to make contributions to the thinking of the group, to say what they have to say so that all can understand. In short, the group setting is much more effective for learning to communicate than is the one-to-one relationship of the tutorial lesson.

Group instruction then is not merely a poor but economical method of replacing individual tutoring. Rather, group instruction is one more tool in the teacher's storehouse of educational techniques, a technique which uses children's inherent characteristics of gregariousness and curiosity to help them develop and grow as rational, contributing individuals and citizens. But this sort of development does not come automatically when children are put together in classrooms. Instead the teacher has certain tasks to perform if group instruction is to be a positive force in the education of children. First, he considers the various objectives which he wishes to reach. Sometimes his class works together as a single unit. Sometimes he has the children working

in sub-groups of varying sizes of anywhere from two children to ten or more children. At times, the sub-groups are brought together for special academic work or for special corrective work. At other times, the groups come together because of social or emotional needs. But no matter whether the group is sub-divided or whether it works as a whole, the teacher will do the following kinds of things.

The teacher guides the discussion; he brings in information where necessary; he helps the children generalize from their data; he helps them see how these generalizations may be applied in many situations; he raises new problems growing out of the completed work and leads the children into finding new problems. In short, group instruction is much more than "teacher telling" and "children listening"; it is the teacher leading the group to build a whole, a unified picture of the ideas being studied.

Summary

As with almost no other area of the curriculum, science materials offer the teacher opportunities to capitalize on the many developmental phenomena which have been discovered about children. Just note. The child is an explorer; science gives him a chance to explore. The child is a problem solver; a science program can and should be built around opportunities to solve problems. The child is a searcher after himself and his world; science programs should demand that be find and make rational decisions about bis world. The child is a social being; a science program provides opportunities for him to work with his peers in a give-and-take situation where he brings his ideas to the group and where be takes ideas from the group.

We must apply what is known about the way in which children grow, mentally and emotionally as well as physically; what is known about

readiness for learnings and about optimum times for teaching; what is known about transfer of learnings from one situation to another; and what is known about group learning. All of these theories, and principles, and facts can be employed and exploited in an elementary school science program. Each of these sets of ideas provides the teacher with a series of roles that he must play. Sometimes he provides information for his students; sometimes he leads the group in synthesizing its ideas; sometimes he helps individual children; sometimes he works with the whole group. An understanding of the nature of the child and the application of this understanding can be used to set up practical and operative classroom programs in science.

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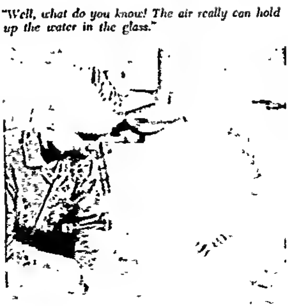
"Just how much is 15 pounds, anyway?"

"Well, what do you know! The air really can hold up the water in the glass."



1. *"If we reduce the air pressure in the bottle, the egg will be pushed in."*

2. *"There! I told you it would go in."*

3. Now if I increase the pressure in the bottle, the egg will pop out."

4. "That was quite an explosion, but here is the egg."

She can see that air takes up space.

1. The straw burns in air.

2. You must work fast to see that the flame goes out in carbon dioxide.

III PLANNING AN ELEMENTARY SCIENCE PROGRAM

THE key to any kind of teaching, and certainly to science teaching, is planning. Of course, objectives and goals are essential. So is an understanding of the developmental characteristics of children. But these will remain abstractions until science materials have been carefully interwoven with them to build specific plans. This chapter considers the planning of a science program. Three phases of planning will be discussed: first, the over-all school plan and its related grade programs; second, the plan of a specific unit in science and the relationship of its subject matter to the over-all goals; third, the daily lesson plan and its part in implementing the science unit and in building the total program.

During the past thirty years, as science found a place in the elementary school curriculum, more often than not the program was left in the hands of the individual teachers. Consequently, the program was haphazard and disorganized. If the teachers in a given school happened

to be oriented towards electricity, a child might learn at several grade levels to connect an electric bell so that it rings. All too frequently, however, the teachers had little interest in or information about science. In this case, the student might find himself limited year after year to pressing and mounting the beautiful leaves of autumn. Without over-all school planning, the material of the curriculum often was determined solely on the basis of a teacher's likes and dislikes.

But the situation is fast changing. The teacher going into a school today is likely to find a science curriculum that is being developed for the entire school. Perhaps the teacher will be called on to help in the continuing development and evaluation of existing programs. In any event, whether he is called on to help build a new science program, or to examine, evaluate, and revise an existing one, he will need to know what goals should be established for the over-all program. There are three such goals for elementary school science.

OVER-ALL GOALS IN ELEMENTARY SCHOOL SCIENCE

GOAL I. The elementary science program must help the individual develop increasing ability to understand and deal with his natural environment.

Thus, as the child works in science, he learns to extend his view of his environment, to observe more of the details, and to see new relationships among the things around him. He learns to explore and understand the phenomena of nature and of the man-made environment. He uses all his senses to learn more of what is around him. And the teacher helps him to fit what he sees and feels and smells and hears into an organized and unified whole. Occasionally he will be introduced to instruments which will

help him extend his horizons even further. Thus, as he uses the magnifying glass or the microscope or the telescope, his vision is extended into new worlds.

GOAL II. The elementary science program must help the individual understand the methods, techniques, and attitudes of science so that he may develop a more rational approach to *the solution of his current and future problems.*

Children are problem solvers. Elementary science offers one of the best media through which this problem solving ability can be cultivated and extended. As children grow, their interests extend from the immediate to the more remote. As they mature, their ability to do abstract reasoning develops. In both of these developmental areas, science can be used to help children. The tools of science can be used as important educational methods through which children's growth in these two areas can be encouraged. Mathematics and logic as well as the physical tools of science must be built into the science program in such a way as to encourage the extension of the ability to use abstract ideas.

GOAL III. The elementary science program must help the individual recognize the interrelationship of science with all other human experiences.

Since the society in which we live is a whole and interrelated one, almost every social question has its scientific components. Many political questions have scientific aspects, and the personal problems of each individual are interwoven with science questions which each one must answer if he is to live more effectively in today's world. Thus, the general curriculum, as well as the specific science curriculum, must help the children find and understand the interrelationships which exist between science information and concepts on the one hand, and social, personal, and cultural information on the other.

MAJOR SCIENCE GENERALIZATIONS

In order to translate these general goals into a definite curriculum pattern, the body of science information must be broken down into broad areas which may then be used as the bases for the curriculum. In other words, there can be no science teaching without science. However, it is not the function of the elementary school to teach the organized disciplines of biology or chemistry or physics or astronomy. Rather, the broad generalizations which have grown from these disciplines must form the base of the elementary program. There are a number of ways in which these generalizations can be stated. No matter how they are stated, the list will in some way include the following:

1. There are many kinds of living things and they are interdependent.

2. There are many forms of energy which can be changed from one to another, but most of the energy which men use is derived from the sun.

3. The earth is a small part of a vast universe containing other planets, stars, and astral bodies.

4. The earth's story, its history and current condition, can be read from its rocks, soils, and waters.

5. Living things are dependent upon the earth and its atmosphere and the sun for their food, their shelter, and their very lives.

6. Men have learned how to use natural forces, both chemical and physical, to make their work easier.

7. Men must use their knowledge of science to keep themselves healthy and to improve society.

Generalizations such as these are the end results of the efforts of men of science over many centuries. These are a part of our

need to revolve around the earth as the earth revolved around the sun. And, of course, the children would want to put the man-made satellites into orbit around the earth also. Things would get quite crowded at the center of the field. Why not move the children further apart? Why not let one foot equal 10,000,000 miles? That would relieve the congestion.

Here is the key point. If one foot equals 10,000,000 miles, then the child who is to represent the planet Saturn would have to be about ninety feet from the center of the field and would have to walk in a circle with a ninety-foot radius. (It must be made clear that the orbit of a planet is really an ellipse.) The one who represents Pluto would need to be about 370 feet from the center (the sun) and would have to walk in a circle with a radius of 370 feet. The field just would not be big enough. If the planet Mercury were represented as 3½ feet from the sun, then to get the whole solar system laid out in proportion would take a field four or five times the size of a football field! And even if the smaller scale is used (one foot equal to 30,000,000 miles), the model solar system barely fits onto the football field. Experiences of this kind can make children understand something of the meaning of *vast.* The children who have had the opportunity to represent the planet Pluto will remember for a long time the distance and loneliness of space.

Similar activities with sizes need to be experienced. If the earth is represented by a tennis ball, then the sun would be a ball of such a size that it would just fit into a room about fifteen feet high, about the height of a school cafeteria. Of course, no one could get such a big ball for school use. Trying it the other way around, suppose the sun is represented by a big plastic beach ball about two feet in diameter, then how large would the earth be in order to be the correct proportional size? It would be represented by a ball about the size of a large pea. And, while Venus could be about the same size, Mercury and Mars would be only about

half the size of the pea—perhaps the size of a small bead or BB shot. It is this sort of thing that we must plan to do with concepts. They must become more than mere words. They must become *realities for* the *children.* Words like "light year," "planet," "asteroid," "satellite," "star," "galaxy"—all of them need the most concrete kinds of experiences that the teacher can plan. These actual experiences must be the foundation of the abstract concepts of the units about the vast universe.

This gives a basis for planning for the grades. It is not that one grade studies planets and another studies stars and a third studies galaxies. Rather each grade works on the concepts which are appropriate for the children in that grade. Third graders do not seem ready to comprehend the huge numbers involved in working with stellar distances. Nor are they particularly interested in such distances. This is no immediate problem for them. Fifth or sixth graders, on the other hand, can understand such numbers. Then, while a class might study about stars in a third grade, they would not study about distances to the stars. They would be more likely to find out about our own star, the sun. Or they would learn about the constellations which the stars form and where to find them in the heavens. They would make drawings of the constellations and star charts. Their visit to the planetarium would have a different purpose than that of a sixth grade. The younger children might go to see "The Stars of the Winter Sky," while the older children might be concerned with the seasonal positions of the earth with relation to the sun. Each group would go for entirely different reasons and to crystallize entirely different generalizations, each set suited to the needs of the given children.

The same approach applies to the expansion of all of the basic generalizations. If a class is learning about the interrelationship of living things, the children can learn it with grasshoppers or with ants or with flies or with moths. It is not the insect or animal

that is the prime factor, it is the concept, "There are many kinds of living things and they are interdependent," that must be firmly fixed in the child's mind. The importance of the plants or insects or animals that are studied lies in the fact that they give substance and meaning to the coocept which is being learned. Thus, the ant is never the core of a unit for a given grade. The core is a concept. In a lower grade it could be "Some Animals Live in Communities." In an upper grade it could be "Man is Affected by Insects." In either case, the ant could be used to build the desired thesis without undue repetition of factual informatioo. The examples which explain the coocepts come from whatever body of information is appropriate. The coocepts themselves are carefully fitted to the maturity levels of the children.

If only specific science information was assigned to given grades in the elementary school, then the goals and objectives of the elementary science program would be lost. The science that is taught in the elemeotary school cannot be broken down into its many subdivisions such as histology and embryology and cytology. Rather these materials must be brought into a unified whole. Over the course of the years of the elementary school, the child needs to gain those understandings of his pbysical environment which are necessary for self-realization and appropriate patterns of behavior.

CRITERIA FOR GRADE PLACEMENT OF SCIENCE MATERIALS

What criteria can be established in order that childreo may achieve the over-all goals for elementary science through the mastery of these generalizations? In the first place, it is clear that the material of science must be arranged, in so far as possible, from the simpler to the more complex. Ideas concerning simple electric currents must come before childreo study about

transformers or rheostats. What a magnet can do should come before children study electromagnets and the magnetic fields of generators or motors. Thus, the sub-topics which are developed under any one of the major science generalizations must be analyzed and arranged in order of difficulty before they are placed in the grades. Of necessity, there will be room for question. What is easy for one person is hard for another and vice versa. This does not mean that there should be no attempt at grade placement. On the contrary, it means that there should be enough latitude in placement so that materials developed for a given grade are, none the less, suitable for the wide range of environmental experiences to be found at that level.

Then there is the matter of the developmental characteristics of children and of current theories of learning. There is a great store of information with regard to the ways in which people learn which must be used when science materials are placed at one grade or another. It is known, for example, that younger children learn and understand things more readily when they are provided with many firsthand, concrete experiences. Older children, on the other hand, can grasp abstract concepts which are quite inappropriate for the early grades. Older children can understand things of the past and can differentiate between the immediate past and the long past. Ideas involving concepts of time and space become easier for children to understand as they mature.

Furthermore, the principles which have grown out of the work in Gestalt psychology should be used for the sound placement of science materials. People learn more effectively if they can see the whole of what they are to learn. This phenomenon seems applicable both with younger children and with older ones, as well as with adults. Thus, in all work, whether it be with concrete firsthand experiences for the very young children or with abstractions presented to older children, there should be a unified

or whole picture which is understandable and clear to the learners.

In addition to these principles, there is also the information available about centers of interest at various age levels. This knowledge of interests is especially important in establishing starting points for the units of work which are assigned to different grades. For example, many six- and seven-year-olds seem to show great interest in animals and their young. This is quite understandable. In our culture, children often have pets, and stories written for children often revolve around animals. This kind of experience is common to most children. In like manner, ten- and eleven-year-olds often are more interested than younger children in the human body and how it works. This interest, too, is derived from their cultural experiences. All such information should be considered when planning for the grade placement of materials in the building of a science curriculum. On the other hand, it is well to remember that children's interests vary from day to day, from child to child, and from community to community. Such variations are to be expected since interests are culturally determined and not genetic in origin. Furthermore, one of the important functions of a teacher is to help children develop new interests. Thus, while the curriculum must take into account the interests of the children, such interests cannot be the sole criterion.

Finally, there are those principles derived from what is known about the problems and needs of children at various age levels. Teachers cannot escape from their responsibility to present to children new and fresh experiences which will widen their horizons and make them aware of their own growing needs. The teachers must choose at a given level those areas of study which they feel will serve children best in this technical society.

Clearly all the criteria for grade placement of materials are interrelated. Children's interests are related to society's demands.

The presentation of science material from simple to complex is related to the development of the child's ability to do abstract reasoning. This interrelationship means that while there is no absolute way of determining the exact grade placement of science materials, a frame of reference can be established based on these criteria. Upon this frame of reference, the scope and sequence of the science program may be built, and each teacher can make specific plans. Knowing what his class has done in previous years and knowing the general curriculum pattern allows the teacher to build his class's science program so that it fits into the over-all school program.

The use of such a frame of reference in the building of a science curriculum will result in the assignment and reasonable division of the science materials throughout the school. But this division must not become a straight jacket. Butterflies must not become "fourth-grade insects." Rather, it becomes incumbent upon the teacher, each teacher, to study what has gone before in science, to know approximately what is to come, and to build his own program on the basis of this information and what he knows about his own particular children and their needs for the year. Insofar as each teacher provides such a program for each group, for each child, a curriculum guide serves its purpose.

The criteria for placement can be stated simply as follows:

Each major generalization includes many basic concepts. The simpler and more concrete concepts should be taught in the primary grades. The more complex and more abstract concepts should be taught to children in the intermediate and upper grades.

What is known about developmental characteristics of children and about learning theories should be a determining factor in the placement of science materials.

The information that has been gathered about centers of interest for various age levels should be a determining fac-

tor in the placement of science materials in the curriculum. These centers of interest can provide excellent starting points for the various science units.

The problems and needs of the children as well as those of the expanding society in which they live are necessary guides in the development of a science curriculum.

PLANNING A SCIENCE UNIT

Now the individual unit can be planned! It should be constructed so that it will contribute to the attainment of the overall goals of elementary school science; so that it will be concerned with some phase or phases of one of the major generalizations; and so that it will conform to the criteria for grade placement of science materials. It necessarily includes concomitant learnings and becomes a balanced part of the curriculum. To see how this is done, a sixth grade unit on "Microbes and Men" will be discussed. This unit is a phase of the generalization "Men must use their knowledge of science to keep themselves healthy and to improve society."

JUSTIFYING THE UNIT

There are many areas that could be chosen for effective science units for sixth grades. Why should one be chosen rather than another? Planning requires that the teacher think through his reasons for making selections, and this needs to be done in the light of the four criteria which have been established. Why choose "Microbes and Men"? Sixth graders are about eleven years old. Of course, they are interested in themselves. All of us are from the time we are born. The "Men" part of the unit fits

very well. But the "Microbes" part is important because of the experiences that the children have had. Experiences are determinants of interests. In our culture children have had many experiences which have led them to some awareness of microbes. Mothers have ordered clean hands; antiseptics have washed their cuts; "shots" have protected them from many diseases; they have all had experiences with doctors and with medicine; many have been in hospitals and have had operations; almost all have been exposed to discussions and considerations of these matters through television and radio. From these many experiences comes a desire to know more about micro-organisms.

The interest in micro-organisms that the children have developed in the course of five or six years of school will depend upon their experiences; the more varied their experiences, the more varied will be the interests. This means, of course, that second graders will also be interested in micro-organisms. After all, they too have been filled with shots from the time that they were born—vaccinations, tetanus anti-toxins, Salk shots, and half a dozen others. So experience alone is not enough of a base for placing the material. But these eleven-year-olds have some things which they did not have at seven. They have, first, the mental maturity to work with the abstractions that are involved in studying micro-organisms. They can understand microscopic sizes. They can make the necessary analogies between these forms of life and other forms which are larger and more easily studied. They can think in terms of the vast numbers of these organisms, and they can be helped to see how these organisms can be used or destroyed.

Furthermore, there is another reason for placing this unit at the sixth grade level. Now the children can learn to use a microscope. Now they really can see what is in the field of a microscope or on the screen of a micro-projector. They can prepare simple culture media and can work with slides of both living

and nonliving materials. In other words, the work which the children did when they were eight and nine years old, when they tried out microscopes and looked through them at newsprint or feathers or hairs or onion-skin cells, is now bearing fruit. The children have the physical capacity and the manual dexterity to work with the materials needed to carry on this unit, and they can attain new and more mature levels of understanding through their further use. So the unit is placed.

STATING THE OBJECTIVES

In this unit, as in most elementary science units, all three of the over-all goals can be brought into focus. There is material in the study of micro-organisms which can help each child develop increasing ability to understand and deal with his natural environment. There is material which can aid him develop more rational approaches to the solutions of his problems. Certainly, there is material in this unit which can point up for him the interrelationship of science with other human experiences. However, it is necessary to state the immediate objectives so that they are specific and exact rather than broad and general. The objectives must be stated so that the desired outcomes are attainable and measurable. The objectives are the "what" of the unit; they tell what is to be strived for, and they should tell it in clear and precise terms.

The immediate objectives of the unit need not be defined in terms of all of the over-all goals. Any immediate objective can work toward the satisfaction of one, two, or perhaps even three of these goals. Thus, a statement of one of the objectives for this unit might be:

> To help the children develop an understanding of some of the conditions necessary for the life of micro-organisms.

If this objective is attained, then clearly the children will have greater ability to understand and deal with their natural environment (Goal I). As the children study the conditions necessary for the life of micro-organisms, they discover new worlds. Furthermore, since the growth of micro-organisms lends itself to many experiments which the children can set up and perform, they can learn more about rational approaches to the solution of problems (Goal II). With such questions as, What do these organisms eat? At what temperatures do they grow best? What does light do to them? What does water do to them? the children not only can set up real problems but they can find some answers for themselves. This is the way in which they can learn to be rational. Certainly, then, the first and second over-all goals will be partially satisfied as this specific objective of the unit is met. Other objectives of the unit will satisfy the goal of pointing up the interrelationship of science with other human experiences (Goal III).

Here is a typical list of objectives and related goals for a unit such as this:

To help the children develop an understanding of the conditions necessary for the life of micro-organisms. (Goals I, II.)

To help the children develop an understanding of some of the ways in which men control and use micro-organisms. (Goals I, II, III.)

To help the children learn simple laboratory techniques with which they can grow and prepare micro-organisms for observation and study. (Goal I.)

To help the children learn to use a microscope and a microprojector. (Goal I.)

To help the children develop an understanding of the methods and contributions of leading scientists of the past and present who have worked in the study of micro-organisms. (Goals II, III.)

METHODS, MATERIALS, AND ACTIVITIES

Now comes the "how" of the unit. Each objective, if it is to be attained, must be thought through in terms of a wide variety of specific activities. Each child must have a chance to study in such a way as to help him grow toward the stated goal. Consider the first objective:

To help the children develop an understanding of some of the conditions necessary for the life of micro-organisms.

The key word here is "understanding." To understand means to apprehend the meaning of, to apply intelligence to, to render judgment on, to be expert with. This kind of development comes from a variety of experiences. The very nature of "apprehending" implies many experiences of a sensory character. Thus, the teaching and learning situation must be planned to allow for a wide range of experiences.

How does a child learn? New learnings take place as old knowledge is fitted together with new facts and experiences to form new and more comprehensive patterns. So the first thing that must be done is to review. The children must be helped to find their common understandings, to call to mind the information which they already have about a given topic. This review can take many forms but it is most useful when it is a shared experience and when all of the children in the group have a part in establishing a starting point for new learnings.

Once the review has been completed, the teacher sets up situations in which the children can have firsthand experiences from which they can "develop an understanding of some of the conditions necessary for the life of micro-organisms." Learning is

an active, not a passive process, and each learner must engage in it himself. The teacher sets the stage by providing each learner with opportunities to do his own problem solving. Planning activities to allow the children to develop understandings in this case means planning activities which will allow each child:

1. To prepare a variety of media (normal salt, hay, Ringer's, etc.) in which they may attempt to grow protozoa.

2. To prepare a variety of agar culture media and attempt to grow bacterial colonies.

3. To design and try to carry out some controlled experiments on the factors which encourage or retard the growth of bacterial cultures. (Example: What is the effect of direct sunlight on the growth of bacterial colonies?)

4. To see how health department and hospital laboratories grow micro-organism cultures.

5. To hear about the conditions which are necessary for the life of micro-organisms both from the reports which other children give on the information they have gathered and from experts in the community.

Each of these activities will take some time. And each will require its own special methods and materials. The first set of activities can be planned so that every child has an opportunity to grow his own protozoic cultures. Here are some of the questions which may arise as they work in this area: How can protozoa be grown in the classroom? Will they grow in tap water? Will they grow in pond water or swamp water? Will they grow in distilled water? In short, the children need a chance to study and try out various media for growing these cultures of minute organisms. But it is not the growing of the organisms per se that is important. The important factor is the knowledge and understanding of fundamental concepts relating to the growth of common protozoa which the children gain from ex-

perimenting and from reference work. These organisms need certain kinds of aqueous solutions in order to have optimum growth. They will not live long or grow well in distilled water. On the other band, given some simple salt solutions, these organisms can be cultured quite effectively. The children need to find these things out and, from their experiences, build the major generalizations that ". . . living things are interdependent . . ." and ". . . are dependent upon the earth and its atmosphere for their very lives." This is the basic reason for this activity.

Of course if the children are to carry on these kinds of activities, the teacher must make the necessary materials available to the class. If certain salts are required for the preparation of media, the teacher should have those salts on hand. If balances and weights are necessary, they should be provided. Of course there should be reference books which the children can use and books for the teacher's use. All this is part of planning for the unit. Each of the activities must be planned in this way. The experiments which the children do should be simple enough so that they can be performed both in a comparatively short time and with a comparatively limited background of information.

The obvious way to see how laboratories grow micro-organisms (activity 4) is to visit a hospital or health department laboratory. Here again planning is important. The people at the laboratory have to understand in advance what the purpose of the trip is. They should know that the children are coming to learn about how micro-organisms are grown in the laboratory so that they focus their explanations on the problems which are of concern to the class. The trip should be planned so that the children can see that the things which they are doing in the classroom are basically the same as those that are carried on in the laboratory and that the laboratory work is only a more controlled, more accurate, and more complex operation. If a trip is impossible, then a film can help the children gain this understanding.

As a result of these learning experiences, the children will develop a group of generalizations or concepts. From the above activities, some of the generalizations derived might be:

Some microscopic animals and plants grow well in pond water.

These animals and plants do not live very well in distilled water.

Certain salt solutions foster the growth of micro-organisms.

There are many kinds of solutions in which these micro-organisms do not grow.

These organisms need food in order to live and grow.

As the children develop these concepts and many more, they are learning a phase of the major generalizations "There are many kinds of living things and they are interdependent" and "Living things are dependent upon the earth and its atmosphere for their very lives." They are coming to understand some of the conditions necessary for the life of micro-organisms. In other words, they are achieving the objective which has been established. One important way of measuring whether or not the children have met the objective is to note how well they are able *to formulate such concepts.*

Each of the objectives of the unit must be so considered. Just as the first objective was outlined and a series of activities and related methods and materials were planned, so each of the other objectives must be examined and organized. Take, for example, objective 4: "To help the children learn to use a microscope." The development of this skill requires several things. First, there must be microscopes available. They do not need to be expensive instruments such as are found in college or professional laboratories, but they must be good enough to show some of these simple animals and plants in fair detail. These

instruments will have been used by the children before their work on this unit, but they will need to review the use of the instruments and they will need time to develop the techniques for observing living materials. Furthermore, good planning will require that the teacher find ways of showing the children the kinds of things which they may expect to see under the microscope. Perhaps he will plan to do this with a micro-projector, first showing them a slide of living materials on the screen, and then having them look for similar things on the slides under their own microscopes. If there is no micro-projector available, the teacher will procure charts and pictures which can be used to show the children what they might expect to find. In any event, developing the skill of using a microscope takes time and should not be hurried.

The last objective, "To help the children develop an understanding of some of the methods and contributions of leading scientists of the past and present who have worked in the study of micro-organisms," poses entirely different problems from those presented by either the first or the fourth objective. While "understanding" is again the key word, here there is a need for a different kind of understanding. In this case, the children will need to do reference work. All of our present day knowledge in science and, for that matter, in all other areas is built upon what was learned in the past. And all of the future must be built upon the present and the past. So our children must be helped to explore the past and see its close relationship to the present and the future. This is no simple task. In the first place, methods which scientists use vary from man to man. Secondly, men failed more often than they succeeded. The greatness of science and of scientists lies not so much in the wonderful things that they found, but rather in the awesome handicaps and terrible odds that they overcame in order to find new truths. For too long, we have led people to believe that science was simply a matter of paying attention to one's work and doing some studying. Progress in science comes from the slow winnowing

of a few tiny kernels of ideas from the chaff of mistakes, wrong leads, and failures. The man who is a scientist is the man who has the infinite patience to go on, time and again, after the failure of one and then another or a third or a fourth or a hundredth or, as in the case of Ehrlich, the six hundred fifth idea until finally he comes up with "606"!

To learn about the achievements of such men as van Leeuwenhoek, Pasteur, Ehrlich, Lister, Waksman, and Salk requires that the children have sources from which they can gather pertinent information. The teacher must, therefore, explore the availability of materials in the school or town library to make sure there are sufficient resources so that each child can have reading materials available to him when he goes to the library for his references. In using biographies of men of science and in repeating some of the simpler experiments that these men performed, the teacher must be careful to make sure that the children know of their failures as well as of the successes, of their very human qualities, and of their motives in finding new solutions to the problems. It is not, then, only their science that will be included in the plans for the unit, but also the stories of the men themselves. Often the teacher will need to search out these stories for the children from adult materials and read them or tell them to the children. There are many good examples of this human side of science to be found in the life stories of scientists.

As the children work toward the fifth objective, the following generalizations well might emerge:

Scientists are very patient and keep trying to find the answers to the problems which they have set for themselves.

Scientists often make mistakes and think that things are true which are later proved to be false.

Scientists are like all other people. They have the same kinds of emotions: love, hate, jealousy, envy, fear, and happiness.

These emotions affect their work just as emotions affect everyone's work.

A scientist shares his work so that other scientists can try out his experiments and find out if he is right or wrong.

These and other similar ideas will be formulated if this objective is met through such activities as have been described. And, of course, as the work progresses, the teacher will evaluate continually the progress of the class in terms of their ability to formulate just such generalizations.

Following this pattern, the entire unit is planned in advance. Each day's lesson, however, presents its particular problems and the unit can be carried out successfully only if daily plans are given sufficient consideration.

PLANNING A DAY'S LESSON

There are, and should be, many ways in which the unit plans can become realities in each day's work with children. In fact, if a day's plan becomes something that is routinized and formalized, then the class program will become stilted and very boring both to the children and to the teacher. Each day's plan can be unique. Each day's lesson can be something to which the children and the teacher look forward. But there are three factors which must be considered in the preparation of any day's plan: What have the children learned? What are the children working on now? What does the teacher want them to do next? These things the teacher must know at any given time since they supply the leads for the daily lesson plan.

However, there are other factors which should be considered in daily planning. As the teacher works with a class of children, he

gets to know them. He knows about how much work they can do *in a given period of time*. He knows that he must plan about this much for a half hour and that much for an hour—and that it is not always just twice as much. And he knows that he had better have all the necessary materials prepared. If he needs twenty-five test tubes for today's lesson, they should be in the classroom in the morning. And he knows that he had better try out the experiment beforehand to make sure that he can do it and that he is aware of the possible area where the children will have difficulty.

These points then are essential for any effective lesson plan. But the specific way in which a teacher prepares a daily lesson plan *is a very personal affair, something like the unique way in which* one talks, or acts, or teaches. Mr. Jansen, who teaches a sixth grade, does his planning in the form of a running log. He uses a notebook and allows himself plenty of room for comments on each of the activities, each of the statements of goal, each evaluation, each set of materials, and all of the references which he uses. Thus, as he goes back over the log of a completed unit, he can see how he progressed from day to day. Mr. Jansen has been working on a unit on micro-organisms with his group. Here is what one section of his notebook looks like:

Evaluation of 11/2

Micro-projector showed variety of protozoa well. Children were particularly fascinated by heart beat in daphnia. Can use this for introduction to unit on functions of organs of body. Need to review variety of materials seen and lead into functions of various nutrients and other factors necessary for life. Jerry and Linda seem confused about size of daphnia. Check Bob and Ed on meaning of "culture."

Plans for 11/3

GOAL FOR DAY: Children should understand the necessary factors for a culture-growing medium—water, salts, nutrients, elimination of toxic substances.

PROCEDURES: Review micro-projections. Show daphnia again and check on size problem (Jerry and Linda. Others too?). Find and identify various materials in the micro-field—water, plants, animals, grains of sand. Show drop of tap water and compare it with pond water.

QUESTIONS TO BE ANSWERED:

What do animals and plants need in order to live? Key ideas: food, proper environment (temperature of water for these mirco-organisms, air, etc.), factors necessary for both plants and animals.

How can we make a medium for growing micro-organisms? Key ideas: Can use pond water. (What is it?) Can make a solution. (Use Guyer for information on how to make medium. Guyer, M., *Animal Micrology*, 5th Ed., Chicago: University of Chicago, 1953.) Let Jerry, Sue, and Ed look up formula for Ringer's solution in handbook and prepare medium. (Get some calcium chloride from Jim G. at the high school.)

How can we make a good medium out of tap water? Key ideas: We must add food and remove poisons. To remove chlorine, allow water to stand overnight. (Compare to allowing water to stand before putting it into an aquarium.) Can then add hay infusion for food. Can add rice too. Or can try other foods—bread, meat, sugar, etc.

How about distilled water? Key ideas: Difference between distilled water and tap water. Add minerals. Ringer's solution is one result. Can we drink Ringer's solution? What is in our tap water? (Can get information from Mr. Luther at the Water Department. Have Jill and Jaimy—or Sue and Alice—check with him.)

SOURCES FOR STUDENTS: Use following books with stated children for special assignments:

Buck, *In Ponds and Streams*—Ian

Schatz & Reidman, *Story of Microbes*—Sarah and Jerry

Selsam, *Microbes at Work*—Ed, Janet, Ellie and Sue

Schwartz, *Through the Magnifying Glass*—Tom and Mariann

Use high school biology text (pp. 130-138) for pictures. Also, Janet can use this material. Use science texts (pp. 82-91).

General sources:
Compton's
Britannica Junior
Columbia Encyclopedia
World Book

Concepts and techniques to be checked:
Can children use the balances for weighing out the necessary salts?
Do they understand the requirements for a general medium?
Do they know the relationship between pond water and a prepared medium?

Follow up: Lead into preparation of cultures from each of several groups for experiments on effect of light on culture, effect of ultra-violet on culture (ask Martha to bring her father's ultra-violet lamp), effect of different foods, effect of different temperature. (Have Bob, Bill, Jaimy, and Ed repair incubator during shop period. Be sure to remind Mr. Jones that they are planning to do it.)

Evaluation of 11/3
(*To be made after the class has been taught.*)

This kind of plan is flexible. Mr. Jansen can change his approach, his work, his methods, and even his materials to fit the needs of his group at any given time. But this is only one possible way to make a plan. Exactly what method is used in making the daily plan does not matter. What does matter is that it must be made. Here is a check list which can be used for all plans.

1. Know what the group has done. Know it quite well. How much of the material under consideration do the children understand? How thoroughly do they understand these items? Does there have to be review again today?
2. Know where you are trying to lead the group. Where do you want the children to be tomorrow? Even more im-

portant, where do you want them to be in three weeks?

3. Know the generalizations towards which you are leading the group in today's lesson. What big, broad idea is to come from today's work? And how is the work you are doing today going to help the children get there?

4. Know, in a general way, which children need special attention in today's lesson. Is the lesson something that can be especially helpful to this child? Is the lesson something that will give that child difficulty?

5. Know the material that you are going to use. If it is a film, have you previewed it? If it is an experiment, have you tried it out? Don't just trust to memory. You will have forgotten something.

6. Have your materials ready. Do you have the projector? Do you have the necessary test tubes or wire or sticks or plants or snails or whatever you need? Get them far enough in advance because it is certain that you will find some essential thing hard to get.

7. Know how you are going to summarize and evaluate the lesson. How will you find out if the children know what you have been teaching? What kinds of questions are you going to ask them? What kinds of summaries are you going to have them make? What kinds of behavior will you expect from them that will be different because they have learned this new material?

8. Know tomorrow's plan as well as today's. Even the most experienced teachers plan too little sometimes, but young teachers do this most often. They plan what they think is enough for half an hour and they use it up in the first ten minutes. Then what to do for the next twenty minutes is a nightmare. Especially when you first start to teach, plan at least five days in advance so that you can go on to the next day's lesson if necessary. But be sure to revise your plans each day.

9. Plan to go slowly. Even the most capable children need time to absorb what you are teaching. Just because you have said something does not mean that the children have learned it. A good lesson plan allows the children time to learn.

Of course, making these plans will take time. A young teacher can expect to spend at least as much time planning his work as he does in actual teaching. That is why the teacher comes to school before the children in the morning. It is why the teacher goes home long after they have left. But it is worth the time. The children will learn.

Summary

It is almost axiomatic that the success of a teacher is directly proportional to the amount of planning he does. There are two basic areas into which a teacher's plans are grouped:

1. He plans for the children as individuals. He knows that each child has certain weaknesses, certain strengths. He plans his work so that each receives the support he will need to grow towards maturity. Of course, some children will receive more help from a given teacher than others. But if the children are considered when the teacher makes his plans, then more children are likely to receive more help from him than if he made no such plans. He plans to watch continually the growth of the children as they progress in their work from day to day and to note their reactions and record them so that he can have a basis against which he can measure his work and theirs. He will use this record to help him see what he has done with the children and to give him ideas about what he should do in the future.

2. He plans for the subject matter. He knows the generalizations which he is trying to teach and he has thought through the experiences which he wants the children to have so that they are more able to reach these generalizations. He makes sure that all the necessary equipment and materials are available. He does not expect each child to learn from each experience in exactly the same way. But he knows that without planning the science to be taught, then no science will be taught.

IV SETTING THE STAGE FOR SCIENCE IN THE CLASSROOM

SCIENCE and technology are part and parcel of modern life. In all daily activities these areas are continuously having an important impact on us. No child is unaware of this fact. Although few children can verbalize it, all of them live and act differently because of this technical, industrial society. It is the rare American child who lives without electricity, radio, automotive transportation of some sort, and some modern medical care. Science needs no justification for inclusion in the curriculum beyond its tremendous significance in our lives.

But the very interweaving of science into the warp and weft of society means much to teachers. Here is one branch of learning where little artificial motivation is needed. Children come to school primed to learn in this area. The wide range of interests, the broad background of information, and the normal childish curiosity with which they come to school can be the foundation of wonderful work in the schools. The problem is not one of creating

interest in science. Rather, science programs must be built so that both the pre-existent interest and the natural curiosity about science are fostered and cultivated in children.

If this interest in science is so strong, how does it happen that so many young people avoid science courses in high schools and colleges? What happens to this early interest? Obviously, teachers must be partly responsible for its disappearance. There has been a failure to extend and expand these natural childhood interests and to lead the children to greater appreciation of science and to further work in the field. How can what is known about the nature of children be used most advantageously to motivate a science program?

THE MEANING OF MOTIVATION

It has been shown that man is an active being. He is naturally curious, naturally social, naturally a problem solver, naturally a thinker. The healthy child has within himself all of these characteristics. Motivating means making use of these characteristics for teaching purposes. Situations must be set up which make use of this inherent curiosity. Materials which establish problem-solving situations for children must be brought into the classroom. The fact that the child needs social approval must be considered and used. The child, as a thinker, must be helped to find out who he is and how he fits into his society and his world. Good teaching means using these inherent characteristics to help students solve personal problems and develop competencies to meet the variety of situations which they will face.

Since the individual has inherent characteristics which cause him to act in certain ways, teachers, by using these innate factors, can help him to gain maturity and an understanding of his world.

There are a variety of forces which the teacher, the school, and society generally use to help children learn and grow.

MOTIVATING FORCES

Inherent in any area of subject matter is the value of that area. Science is a tool for understanding the world. It offers both information which is of value and techniques for working with this information. The rational approach to problem solving has a fascination for all people and can be learned. Thus, within this area of concern there are built-in motivational forces. This first type of motivation calls into use the intrinsic values of the material to be studied.

Next, there is the factor of individual and group interest in school activities. Again, science is an area which has advantages over other areas. Individual children are already interested when they come to school. The children come out of a culture where this area of knowledge is viewed with great respect, if, indeed, it is not held in awe. There is little difficulty in capturing interest in the body of material to be learned and, if the procedure is sound, of holding and cultivating this interest.

Then, there are the materials for work in science. Learning, without the tools of learning, is often a dull task. Learning from a dog-eared book, learning with nothing more than a piece of paper and a stub of pencil, learning with no way to experiment or try out the new knowledge, all of these can dull the most fascinating subject. Hearing alone, and even hearing and seeing, make for comparatively poor learning and retention. On the other hand, experimenting and using materials to try things out makes for functional learning. And science, above all other fields, lends itself to the use of materials, to the experiencing of new ideas, to the trial of new machines, to the experiments that make learning so satisfying. Motivation through new experiences and

through the use of a variety of active and passive learning techniques can be produced easily in the area of science.

Furthermore, this exploring and experimenting with the environment has another important function. As children investigate, as they have new experiences, as they try things under guidance, they come to know more about their environment and therefore to feel more secure in it. Security comes with understanding.

Finally, there is the area of motivation through teacher interest. Here is the factor which, though most important, is most likely to be a stumbling block. Many teachers grew up in schools where science, if it was taught at all, was a "sitting down" or a "reading" or a "memorizing" subject. The spark which as children they had for this area of learning was extinguished by sad school experiences. Teachers need to rekindle this spark in themselves. Only as they can develop a real interest in science can they nurture this interest in children.

ELECTRICITY IN A THIRD GRADE

Of course, there is much to be done before a program is started in the classroom. Objectives must be established. The activities must be planned. Materials must be gathered. Teachers must be prepared for the coming activities. Assuming that these things have been done, what are some possible courses of action which can be taken to start a science unit?

The clock in the third grade room reads twenty after eight. Miss Edwards came to school early this morning. With her back to the door, she listens for the first comer. As usual, it is Jimmy, and she is not surprised when she hears his cheerful voice. "Hi, Miss Edwards. Whatcha doin?" "Just a minute, Jim," she says. "I'm trying this out to see if it works."

What do you think Jim will do? If he is like a million other third graders he will dash over to see what is on the table. And, as the others come drifting into the class, the teacher will soon have most of them crowded around her. Just what is on the table? Well, today there are some dry cells, some wire, some miniature sockets, and flash light bulbs. Also, there are cutting pliers and screw drivers. These supplies have been rounded up from various sources—perhaps from the local hardware store, from one of the high school teachers, from the school science storeroom, or from a science supply house.

"We are going to find out about electricity, so I got some of these things for us to work with. I wonder if we can get these bulbs to light. We'd better start class now, but we'll come back to this."

Miss Edwards has set the stage. She has thrown out the challenge. She will not have long to wait for the response. In the planning session this morning Miss Edwards and the children will certainly make sure that there is time for science. The children will be all ready to go. When the time comes for science, there are several ways in which the teacher may proceed. She could, of course, tell the children how to wire the bulbs so that they light. But that would not be good science teaching. She could get the children around the science table and let one or two of them try to light the bulb. And she might have to do that if she had only one bulb, one socket, one dry cell, and very little wire.

But there is a much better way. Miss Edwards has enough materials so that each group of three or four children has a bulb, a socket, a dry cell, and plenty of wire. "Jim, suppose you work with Bill and Ed. Susan, will you work with Jean and Tom? You folks work over at Sue's desk." And so she divides the class, assigning them working areas around the room. Grouping for this kind of work allows for many good experiences. All kinds of groups are possible. Slow children can work with fast ones. Shy children can work with forward ones or with other shy ones or

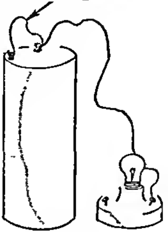
by themselves. Those who do not work well together can be separated. In order for the maximum amount of learning to take place, the best possible grouping has to be arranged.

Now that the groups have been established, it is time for instructions. This is a key point. The teacher must give enough instructions so that the class does not flounder, but she should not give so many instructions that the children have no exploring to do. Exploring, finding out for themselves, discovering—this is the essence of good science teaching. After the groups quiet down, Miss Edwards writes these directions on the blackboard:

To get the bulb to light, you will need
1 bulb
1 socket
1 dry cell
2 pieces of wire
1 screw driver

Her instructions may sound something like this: "Each group will need the things which I am writing in this list. One person from each group should get the things from the table. Be sure you get one bulb, one socket, one dry cell, and two pieces of wire. The wire is not cut, so you will have to use the pliers and cut two pieces each about a foot long. You will also need a screw driver. Now remember what your job is. You must get the bulb to light. One thing more. Remember, when we work quietly, we can work better. Now don't forget to check your supplies."

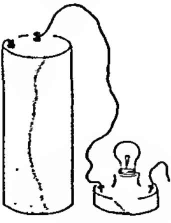
Around the room will be the hum of busy people. They will have many ideas to try. Some will go right to work in a very knowing manner. Some will hesitate. Some will stand around and watch the others. Miss Edwards is not a member of any one group. As the teacher, she moves from group to group with a word of encouragement here, a leading question there, a suggestion to a third group. Jean's experiment looks like this:



Jean's experiment

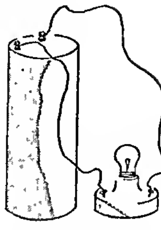
Jean's experiment may ruin the dry cell, and the wire connecting the two poles will get quite hot. Miss Edwards disconnects one pole as soon as Jean has discovered what is happening.

Another experiment looks like this:



Sally's experiment

Another, like this:

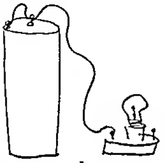


Ed's experiment

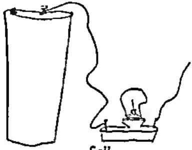
Of course, only the third can light. (And even that might not work; the wires might not be bared; the bulb might not be tight in the socket; the ends of the wires might not be fastened securely.) But soon, one of the bulbs will light. The successful children let out a collective shout. Everyone stops and crowds around them. "How did you do it?" "Let's see!" "I'll bet our stuff is no good."

Miss Edwards has reached another key point in the lesson. Now she must get the class to analyze what happened. "All right, everyone. Let's see if we can figure this out. Stop what you are doing now and come up and sit down in front of the blackboard. Come on, Jo. You'll get a chance to get your light to work later. Yours is working, May? That's good. Now come up here and sit down. Are we ready?" The room quiets down. Good teachers always know the strategic moment when the hubbub subsides to silence. And, before the silence changes again to bedlam, Miss Edwards begins. "Now each group must draw a picture of the experiment. Jean, you draw the picture for your group. Yours

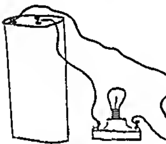
didn't light? That's all right. When we work in science, we have to examine all the things we do, those that work and those that don't work. Now Sally, you draw yours. And Ed, you draw yours here. And May, you put yours on the board over there." Here is what the children may draw:



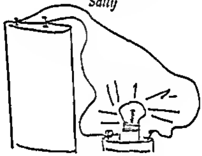
Jean



Sally



Ed



May

Why did some work and others not work? This is the question which the lesson must answer. This is the immediate objective of the lesson. The children must learn that: *In order for the bulb to light, you must have a complete circuit.* What does this mean? It means that you must have a complete path through which the electricity can flow—from the dry cell, through the wire, then through the socket and into the bulb; then the path leads back out of the bulb into the socket and from there back through the other wire to the cell again. Without such a complete electrical path, the bulb will not light. "Jean does not have a complete

circuit. Neither does Sally. Their bulbs will not light. But Ed's experiment has a complete circuit. Why didn't his bulb light? That's right. There must be something else which is stopping the electricity from flowing into the bulb." The analysis of this problem by the class can help them understand the meaning of a *complete circuit* and can clarify *conductor* and *non-conductor* for the children. They are rediscovering the facts of simple electric circuits.

How should this lesson end? Perhaps a series of charts can give the summary necessary for fixing this learning. The class might prepare the charts in the following manner: "Well now, Ed, suppose you go and get your materials and bring them up here." As Ed goes for the materials, Miss Edwards helps the class get ready for this culminating experience. "I think we had better make a list of things we need to do to get the bulb to light. I'll write the things that you tell me and, as I write them, Ed's group can be doing them. Then, when we have finished the list, we can all try to follow the directions which we have written. And after that, there are three bells and two electric motors in my closet. I'll put them on the table here. When your group gets the light working, you can come get a bell or a motor and try it out. All right, Ed, are you people ready? What is the first thing we must do? Yes, Jean? That's right. First, we must have a bulb, a socket, a battery, and two pieces of wire."

As various children give the necessary steps, the teacher writes each on a chart. She should be careful to use words which they can read. She should be careful to be accurate in her statements. If a child makes an inaccurate statement, she should be careful to correct it before she writes it. The final charts may look like this:

1. We must have a bulb, a socket, a battery, and two pieces of wire.

2. We must scrape the *insulation* off the ends of both pieces of wire.

3. We must attach one end of one wire to one of the screws on the battery. Then attach an end of the other wire to the other screw of the battery.

4. We must attach the second end of each of the wires to the screws of the socket. We'll need a screwdriver to do this.

5. Put the bulb in the socket and screw it in tightly.

6. Now there should be a complete circuit. The electricity can flow through the bulb and light it.

Of course, the children will want illustrations for the charts. Since all the drawings they will make will not fit on the charts, Miss Edwards will have exhibits of their work around the room.

Undoubtedly, Miss Edwards has planned for and organized the next steps in the study of electricity; for example, studying different kinds of conductors, or switches, or how a battery is made, or safety with electricity, or some of the things that electricity can do for us. But the important point now is that she has gotten started. She "just happened to have" the materials needed to introduce this study of electricity. Now, the steps that led up to this "fortunate coincidence" can be examined. What were the unique characteristics of the lesson described above? What was it that Miss Edwards did? How was she using the principles of child development to reach her immediate goal of getting a unit on electricity under way in the third grade?

ANALYZING THE LESSON

Children, except as they have been inhibited, are explorers. They are challenged by new situations and new ideas. Miss Edwards

knows this, so she opened the program with a challenge and a surprise. She knew the children would be coming soon and her plan called for this kind of motivational incident. This could have been done in many other ways. For example, a new bulletin board display on electricity could have attracted the children when they arrived in the morning. Or the materials could have been out on the science table and the children could have had the opportunity of discovering them. Or she could have written "surprise" in the daily plan when she and the children were going over the program for the day. Whichever way the work was introduced, the innate and natural curiosity of children would have been the motivational device. Other innate characteristics could have been used for different motivational devices.

Just getting started is not enough. The teacher must set the classroom situation. Miss Edwards did that. She knows the children in the class. Jimmy works well with Bill and Ed. If he tries to work with Tom, neither gets much done. Susan is a calming influence. She and Tom get on well together. There is not the rivalry and competition between them that there is with other children. Jean is with Tom and Susan because Jean needs the challenge of Tom's ability and the calm of Susan's personality. She also brings ability to the group, but it is not too much of a threat to Tom. Henry is not quite ready for a group yet, but Miss Edwards is watching him carefully. Maybe next time the class works in groups, he will be working with Jean. They should make a good pair. Miss Edwards knows which children work well together. She knows which children need to be near her. She knows which children can or should work alone. She knows these things because she has watched the class very carefully and has noted their reactions to one another and to herself. Do teachers make mistakes? Of course. But, when a teacher purposely divides the class, he is more likely to have a proper setting than if he allows a haphazard arrangement to take place. This is one reason why teachers keep such careful records of children.

Proper grouping allows for best work and lets children help each other grow and learn.

Throughout the lesson, the teacher has much more than science to teach. Children need to read and to write. The teacher will know which children should be asked to write at the blackboard and which children should be asked to read what has been written. But there is more to this phase of the work. Do you remember that the wire was not cut? The children needed to cut off the proper lengths. Why? Because this was something they could do with tools. This was a physical skill they could develop, and Miss Edwards gave them the opportunity to develop it. If she had been working with circuits with a first grade, she would have had the wires cut and bared for the children because these are things that most first graders cannot do. Furthermore, third graders can learn to use screw drivers. So she had these tools ready for them to use in fastening down the wires. A lesson plan must provide not only for the development of an important science concept, it also must allow for growth in related mental and physical skills.

All children are different. Some learn quickly. Some slowly. Some have fine muscular coordination. Others are less coordinated. Did Miss Edwards take these things into account? Again, the answer is yes. That is why there were bells and electric motors in the closet. Some of the children will have finished the wiring of the bulb circuits while others are still in the midst of that task. So she had related materials for the faster or more dexterous children. There must be a challenge for each and satisfying jobs for all.

Miss Edwards had much to do. She started the lesson. She set up the groups. She moved around the room. She was able to watch much better that way. Since she knew the frustration level of the children, she was able to help them when this level

threatened to stop their progress. Jimmy's group could work along without much help from her. But another group needed to have her there to ask the right leading question. If she were not there, they would be lost and would stop working. A third group did not need her intellectual help, but the calming influence that she, the adult in the situation, could bring them. A fourth group needed just her smile of encouragement and a word of praise. As she went around the room, she was playing all these roles for the children. And when May's bulb lit, she played a new role. She helped the children summarize their percepts and form a new concept. Now she acted as a guide for group thinking. She helped them summarize what they had seen and learned.

Learning is by no means a simple process. We learn through the use of our senses. For a long time, most school learning took place through hearing. Sometimes the children recited. Sometimes they read. But mostly they listened. However, recent research on how people learn indicates that the more senses involved in a study of material, the more likely is that material to be learned and remembered.

Did Miss Edwards take this information into account in her lesson? She certainly did. When she had the children summarize by re-doing the experiment, that helped them learn. When she had them talk about what they had done, that helped too. When they read the charts, that helped more. And tomorrow, when they illustrate the charts and make an exhibit of their work, that will help even more. All of these sensory experiences will work together to fix this learning in the children's minds. And that is what she wanted.

But there is even more of value in this summary. First, the children can evaluate what has been done. It is just as important for them to understand and evaluate a lesson as it is for the teacher to do so. While reviewing and summarizing, each child

has a chance to find out what be knows and what he does not know. And, of course, the teacher too has a chance to evaluate. Not only can the teacher observe each child and what be has learned, but the teacher also has the very important opportunity to evaluate the lesson and its effectiveness. All this can grow out of the summary.

This lesson is one part of a whole plan. As children learn they gain self-confidence. As they gain self-confidence they become more secure. Then, as they become more secure, they are better equipped to go on to new learning situations. The subject matter that was taught is very important. But quite as important as the information is the development of self-confidence and security. The plan which allowed the children to experiment, to think, to work, to use all their senses in learning allowed them to do all of these important things—to learn valuable information, to develop self-confidence, and to become more secure as people.

As has been pointed out, children are social beings. This too is an important characteristic which may be used constructively for motivation. As social beings, they wisb to gain status both with their peers and with adults. The teacber's approval and praise is important to them. Success in a task, recognition of that success by the teacher and by other children, and the consequent growth in status are all very important in the learning process.

There is another side to this coin. In addition to wanting to gain status, children certainly wish to maintain the status they have. Public humiliation, continual lack of success, rejection by the teacher—all of these things are deteriorating to the ego. They can do much to hinder children's learning.

Children are problem solvers. There is great satisfaction in finding solutions to problems. This is one of the strongest motivational forces for learning. And furthermore this force is self-per-

petuating. This is true because as old problems are solved, they in turn give rise to new problems. From these new problems come new learning experiences. This kind of motivation is particularly useful to teachers of the upper grades. It is to an example of this that we now turn.

ELECTRIC POWER IN THE FIFTH GRADE

For the past several weeks, the major unit of the fifth grade work had been a study of water. Essentially, it emphasized the social studies. Mr. Benjamin was primarily concerned with the importance of water in man's life. The class studied many things—water's use for transportation, water's use in agriculture, water as a determinant in locating cities, as well as many other facts. One of these facts was: water is important for the manufacture of electricity. This is the starting point for a new unit of study. Mr. Benjamin plans to use the problems that have grown from the work just completed as motivation for introducing the new unit: "*Making, Distributing, and Using Electric Power.*"

In summarizing the work that had been done on water, the group listed the following ideas:

1. All living things need water.
2. Water evaporates from the oceans and is carried in the air as clouds until it rains.
3. After it rains, the water goes into streams and then to rivers and then back to the ocean.
4. Then the whole process happens all over again.
5. Boats are used to carry very heavy loads on water.
6. Sometimes water has germs in it.

7. The Water Department uses chemicals to purify the water.

8. Sometimes farmers dig ditches from a stream or a river to get water to their fields. This is called irrigation.

9. Water is used in many ways in factories.

10. Water power is used to make electricity.

11. Men always build their homes where they can find plenty of water.

12. The pioneers always looked for water before they made camp for the night.

This is the list which the children, under the teacher's guidance, developed the day before yesterday. It is formidable, and Mr. Benjamin can be very proud of the children. They have gained much information about water and its importance. They have formulated a number of sound concepts about the role of water in man's life.

CHOOSING CURRICULUM MATERIALS

Today Mr. Benjamin is going to start the study of electric power. Why has he chosen this area as the next unit? Several factors led to the choice. First, electricity is something very immediate in the lives of children. They are surrounded by things electrical, and they know it. Then, there is a certain amount of glamour about the subject of electricity. It lends itself to many motivational experiences. Further, the children already have a considerable amount of information on this subject from their work in previous grades, and Mr. Benjamin plans to use what they already know to continue the expansion of their universe. Finally, he knows that he has a responsibility to help them with the safety aspects of the subject of electricity.

DEVELOPING A NEW PROBLEM

It is ten thirty. The last two boys have just arrived from the music room, and as the plan on the blackboard indicates it is time for science. "All right, people. Please bring your chairs up to the front of the room. Don't forget your notebooks and pencils. We are going to start our work on electricity." The group moves up bringing chairs and pencils and notebooks. Some of the children scramble, some move slowly. This is the same kind of situation that developed in Miss Edwards' class, and Mr. Benjamin handles it in similar fashion. He sets the stage. "Ginny, why don't you and Beth bring your chairs over near the table? Bill, you come and sit here. Ned, you go sit over there with Ellie and Sue and John." What Mr. Benjamin is doing when he asks the children to take certain positions in the group is using his knowledge of the individual children to place them where they can work most effectively.

Once the stage is set, he starts. "We've done quite a bit of work on the subject of water. Fred, why don't you read us the list we put in our notebooks on Tuesday. Yes, that's right. The one summarizing our study of water." Fred is the quiet child, always at the edge of the group. He is a pleasant but rather slow youngster. He must get his chance to contribute to the work of the group. Unless he gets this chance early, he is not likely to have much to say in the discussion. Slowly, Fred reads the list. It is not too long so Mr. Benjamin is able to let him read all of it.

"Thanks, Fred, that is quite a list we have there. And everyone of those ideas is important. But, you know, there is one thing common to all the ideas on that list. They are all 'whats' of water. They tell us 'what' water does, but none of them tells us 'how' water does these things. Sometimes we study the 'whats' as we

did in our study of water. But sometimes we study the 'hows.' Now we are going to study some of the 'hows' of electricity. You already know a good many of them. Remember, you studied some of the 'hows' of electricity when you were in the fourth grade last year? And when you were in the second grade, you studied some other 'hows' of electricity. I wonder if you remember those things?" Hands go up around the room. Again Mr. Benjamin chooses carefully. This time he wants someone who will start off the review with a good example, one that will be familiar to all the children. He does not choose Ned. Ned is a "science bug," and he will have more information to give than the children can absorb. Jackie's answers are generally accurate and to the point, so he seems like a good choice. "Jack, what do you remember?"

REVIEWING WHAT CHILDREN KNOW

"Well, I guess you could say that you need a complete circuit in order to light a bulb. I think that's a 'how' of electricity." "Fine, that's exactly right. Do you think you could show that to us? I just . . ." "Happen to have," the class chants in unison. This is an old class joke. They know Mr. Benjamin has prepared for this situation and that the materials are ready for them to use. "That's right," he laughs. "I have some dry cells and a roll of wire and other things you need to show us how to make a complete circuit. Will you and Fred and Jean and Sally do that for us? We'll go on with some other things while you get that ready. Now, who can remember another 'how'? Bill?" Bill is the youngster who is sitting next to Mr. Benjamin. The teacher called on Bill so that he can have a chance to participate without support. He has been working hard to develop this independence. "We worked with switches too. Do you have any of those—what do you call them? Yeah, knife switches?" "Yes, there are some

in the drawer. Why don't you work with Ellie and set up a circuit with a switch in it?"

Mr. Benjamin calls on children around the room and sets groups to work with various materials. Again, his knowledge of the individual children will help him in determining the groupings. Soon the room is buzzing with work. The children are quite excited about meeting these old friends again. As they get their materials to work, they visit neighboring groups to see what is happening. Mr. Benjamin wanders from group to group giving help where needed.

When things seem to be ready for summarizing, Mr. Benjamin says, "Two more minutes and then we must come up front to show what we have done." There is another buzz of voices. "It's time now. Let's come back to the table." The children come trooping back. "Is your group ready to show what they have done, Jack?" There is a hurried conference and Jackie and Jean bring their materials up to the table. Quietly, in fact, without speaking at all, they light the flashlight bulb. Mr. Benjamin has to do some questioning to get the generalization that comes from their work. "Jack, you said this would show a 'how' of electricity. Can you explain it to us? Ginny, will you be our secretary, please? And, as Ginny puts the ideas on the board, the class had better write them in their notebooks. Yes, Jack?" "You have to have a complete circuit in order to get the bulb to light." Now Mr. Benjamin wants a broader generalization. He turns to someone who can help the class broaden the idea. "Ned, can you add anything else?" "You must have a complete circuit for electricity to do any work at all." "Good, Ned. How can we write that?" Sue says things very well so the teacher turns to her. "Sue, can you dictate this idea so that Ginny can put it on the board?" Sue thinks for a minute. "Electricity needs a complete circuit in order to flow." "Do you all remember what a 'circuit' is? It's a path through which electricity can flow. Maybe we had better put

that word in too. Ginny, write 'path' in parentheses after 'circuit'." Ginny now has this on the board:

1. Electricity needs a complete circuit (path) in order to flow.

Slowly, the class lists more ideas. Each group brings its experiences to the class as a whole. Mr. Benjamin reviews the list of generalizations that the children have developed. He watches for misconceptions and for hazy ideas. He will want to clear those up as he goes on with the unit. By the end of the period, generalizations like the following are on the board:

1. Electricity needs a complete circuit (path) in order to flow.
2. A switch is a machine for opening and closing an electric circuit.
3. When electricity flows through a coil of wire, it makes the coil into a magnet.

"Has everyone copied the list? All right, we'll give you a minute or two more. We really remember quite a bit about electricity, don't we? We'll leave all these things out on the science table and, in your free time, you can work with them."

Mr. Benjamin is on his way! He has reviewed both the facts that the children have learned and the concepts which they have built from these facts. Of course, he needs to analyze the situation thoroughly. Has he done enough review work? Are there certain facts or certain concepts which need more work? Are the children reasonably ready to go on to the next step, a study of how water power is used in the generating of electricity? If they need more review work, it makes little sense to go on. Trying to build further concepts without having a sound foundation has caused more difficulty to more children than any other error made in teaching. *Take your time.* Make sure the children are ready for the new material. Then go ahead.

Mr. Benjamin thinks the children are ready. He has fairly good evidence from the drawings he saw that the children have a reasonable working knowledge of circuits, magnets, switches, statics, and the various jobs that electricity can perform. A few of the children are hazy on some of these items. He notes this and will work with them during the course of the unit. But in general the group is ready, so the next day he begins.

INTRODUCING NEW MATERIAL

"Come on, folks. It's time for work on electricity. Bring your notebooks, your pencils, and your chairs. Let's sit where we were yesterday. All right, are we ready? Yesterday we found out many interesting things about how electricity works for us. But where did we get the electricity we used? What was our source of electricity? Now, don't call it out. Yes, Jim?" Jim does not always speak distinctly, but today he is across the group from the teacher so he must speak out to get his answer heard. "We had those batteries." "Good, Jim. And do you remember another way that we had for getting electricity? Yes, Sally?" Sally is quiet most of the time, she rarely volunteers any information. The fact that she had her hand up is very important. She is a youngster who needs as much recognition as you can give her. "Didn't we get electricity when we used the money and the wet paper?" "We certainly did. Do you remember what that was called, Sally?" Hands go up around the room, but the teacher waits for Sally. She needs to have her chance. "A something-or-other pile." "Well, Sally, the 'pile' part is right. The other part is 'Voltaic.' Remember it was named after Volta, the Italian scientist. We made a Voltaic Pile with a dime, a piece of paper towel soaked in salt water, and a penny."

"Did we have any other ways of getting electricity?" Mr. Ben-

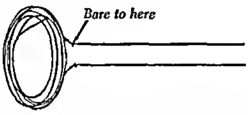
jamin waits a minute while the childreo think. "Well, Ned?" "No, I don't think so." "You are right. We didn't. But do you suppose they use dry cells or Voltaic Piles in the power house to make the electricity we use in our homes?" The children laugh at this. It is obviously impossible to provide power for a community with dry cells. "Well," the teacher asks, "what do they use?" He wants to be sure of a correct answer so he calls oo Sue. "They use a machine called a generator."

"Beth, will you please look in the big drawer of the table? The one oo the right side. Now, will you take out what you find?" Beth brings out a small hand generator. "Do you know what that is? You are right. It's a geoerator. Do you suppose you can get it to work? Try it, Beth." She turns the crank, first slowly and theo more rapidly until the bulb lights. "Well, what do you know! Beth can make electricity. That must be the way they do it at the power station. They must have meo down there who turn the cranks oo little machines like this." This obvious nonsense makes the childreo laugh. "Well, then how *do* they make electricity? Yes, John?" John is a very careful and able youngster. He gives a precise answer. "Down at the power house they use big steam eogines to turn the geoerators. But at some power houses they use big water wheels to turn the generators." "That's true, John. But I'll tell you something else. Those generators at the power station, even though they are much bigger than this one, are really exactly the same as this one. The only big difference is that they use the energy from a steam engine or water wheel to turn them and we use our muscles."

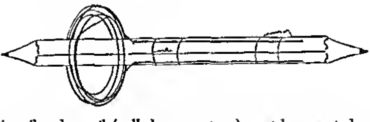
Mr. Benjamin allows the children to examine the generator and find out what it is made of and how it works. They discover that the generator consists of a coil of wire spinning inside a magnet. As they work with it, they learn that the energy which they apply to the crank which spins the coil of wire is transformed

into electrical power to light the bulb. Each child also has the opportunity to experiment further with generators by making a model generator.

Making a small demonstration generator is quite simple and can be done by most ten-year-olds. Wind about six feet of #24 cotton covered wire into a coil on your fingers. Leave the two ends out of the coil and bare them. The coil will look like this:

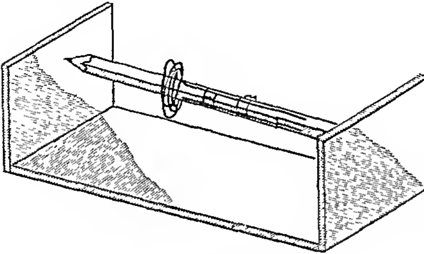


Now sharpen a pencil at both ends and slide the coil onto the pencil. Fasten the coil to the pencil with cellophane tape and fasten the ends of the coil onto the pencil so that the bared parts of the ends are on opposite sides of the pencil. Now, it will look like this:

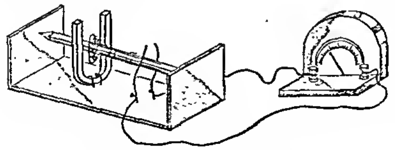


This coil and pencil (called an armature) must be mounted on a stand so that it can spin freely within the stand. A good way of mounting it is to fasten three pieces of wood together in the shape of a "U." Two of the pieces are nailed to the third. The distance between the two is determined by the length of the pencil. The pencil points fit into little holes which have been drilled into the two upright pieces of wood. When this "U"

stand has been made and the pencil is fitted into it, the machine looks like this:



The final step is to bare two long and heavy wires (#16 copper wire) and fasten them into the base of the "U" so that each of them comes up and touches one of the bared wires on the side of the armature. These wires can then be attached to the receiver of a telephone or to a small galvonometer (an instrument which shows the presence of small quantities of electricity). Now, with the addition of a magnet, the generator will look like this:



Wind twenty inches of string on the shaft and pull it gently to spin the armature. When the armature is spun, the meter should

register the presence of a current, or the receiver should click. In either case, the current should be noticeable. If no flicker can be seen on the meter or no click can be heard on the receiver, then probably the two heavy wires are not touching the ends of the coil where they have been bared. Also, it is important that the coil be kept moving. Unless the coil moves, no electricity is generated. But this little machine can be adjusted and made to work, and it is important that the teacher know how to adjust it so that he can help each child make his own model work.

Mr. Benjamin has reached his objective. He has led the children from their work on water into one of the problems that grew out of that study. He is right in the midst of a new unit. Now he can go on. He can help the children find other sources of energy to run their generators. He can let them try hitching up toy steam engines, or model water wheels, or windmills, or something else which they may suggest to their generators. He can take the class to visit a commercial power station. Now he can spend two days or two weeks on generators, depending on the class, the available time, and his other plans.

Summary

Effective motivation means taking advantage of "what comes naturally." There is nothing magic nor anything superficial about it. What is really involved is making use of the inherent nature of the children to encourage their studying and learning. Children are curious about their world. So the teacher piques their curiosity with new and interesting materials. Children are interested in active learning situations. So the teacher motivates by providing such activities. Children are anxious to be accepted and to satisfy the wishes both of the teacher and of their peers. So the teacher sets up situations in which the children are able to gain status and importance through learning activities.

Children need the security of a rational understanding of their world. As they are helped to explore and examine the materials of science, as they are allowed to experiment and reason with these materials, they become much more self-assured and secure. They find new satisfactions in their accomplishments and can then go on to further learnings and further satisfactions. This is the reward of rational thinking. It is self-perpetuating.

Motivation must be an inherent part of the unit which is being planned and taught. It must be appropriate for both the subject matter considered and for the age group for which it is being prepared. Most important, however, the motivating activities are an integral part of the unit and are not just preliminary busywork.

What has been discussed holds for grade three or grade six or any other grade. It holds for a study of electricity or a study of how seeds germinate or any other science area. It holds for units that last two days or two weeks or for a whole semester. Sound motivating experiences are basic to good science teaching.

AN UPPER GRADE
LEARNS ABOUT MAGNETIC FIELDS

Children can understand theory, too.

You do not need much equipment, just a magnet and a few other objects.

The teacher raises pertinent questions leading to valuable learning experiences.

V USING CHILDREN'S INTERESTS IN THE SCIENCE PROGRAM

A LIZARD is a very interesting animal. Watching a chameleon or a skink as it lives in a classroom terrarium can be a fine educational experience. But a lizard arriving at school in a small boy's pocket can be disquieting, to say the least. How does the teacher react when an eight-year-old comes running in clutching a skink in his small fist and delightedly waves it in the teacher's face as he tells how it was sent to him all the way from Arizona? And there are sure to be praying mantis cocoons, wonderful old wasps' nests, fossil and rock collections, thirty-six different kinds of seeds, and one hundred thirty-eight horse chestnuts. Dozens of other things will come to class—birds' nests, insects, frogs, salamanders, and snakes. These specimens can be valuable to the teacher in developing a science program.

It might be well to refer to what has been said about the nature of the child. Remember that he, like most other people, is a collector. In fact, you might examine

yourself for a moment. What have you dooe with your school projects and notes? Chances are that you have them stored away. If you look at them now, you will find them immature and of little except sentimeotal value. Yet you have kept them, probably without having looked at them since you put them away. There was nothing unusual in what you did.

Children have been saving things for as long as there have been children. They have been carrying thiogs to school for as long as they have been going to school. Just look in the pockets of an eight- or a nine-year-old. All kinds of things are to be fouod, from trading cards to live snakes. As children progress from the self-centered and concrete thinking of early childhood to the more abstract and society-centered thinking of tho nine- or teo-year-old, they become more and more aware of their eoviroo-ment. Each thing that they see is new and challenging. They must pick it up, examine it, save it for further study and contemplation. Truly, the world is full of exciting things that must be hoarded for future study.

Children's interests are as wide ranging and as manifold as children themselves. They are profound or shallow, mature or immature, artistic or scientific, sports-ceotered, music-centered, hobby-ceotered, or nature-centered. Sometimes the interests last for a few minutes or a few hours. Sometimes they are persistent and last for days or even months. However, the important thing to note is that while these interests vary from child to child, they do follow a pattern. First graders are likely to be interested in trains, planes, or animals. By fourth or fifth grade there is often an interest in the stars and the universe. And by the sixth grade there is almost certain to be an interest in the buman body and how it functions.

Eventually, children begin to develop the lasting interests which will become the bases of their vocations and avocations. As-

suming that the school provides them with opportunities to explore their interests, they will be more likely to choose among their varied experiences and from their broad backgrounds of information those things which they wish to pursue as long range activities.

With the wide scope of children's interests, the natural question follows: How can these interests be used in building the science curriculum? One of the essential criteria for including material can be stated as follows: The needs and interests of children are a necessary basis for curriculum construction, but they are not a sufficient basis. In other words, materials which clearly help children satisfy general or even specific needs should be included in the curriculum. But such materials will not be the only ones which are included in a good science curriculum. Who ever heard a group of children demanding that the school teach them about conservation? Yet the school must also find an important place for that kind of topic. It is incumbent upon the school to satisfy the demands of society.

Can the school do both of these jobs? Is there time in the school program for both the satisfaction of individual interests and needs and for meeting the demands of society? The dilemma in the situation is more apparent than real. In fact, individual interests are a manifestation of the reaction of the individual to his environment. Thus, since children do not live and grow in vacuums, the interests which they develop come from experiences which they have had with the world. Any interest has both personal and social components. A youngster who becomes interested in fishing is concerned with a personal aspect of the more general conservation problem. Likewise, the youngster who becomes interested in collecting insects has gained a personal interest in an area which has social meaning.

Thus, the teacher who takes children's personal interests into

account often finds that these interests build fuller and richer understandings of the general social problems which he must also include in the program. The variety of personal interests and experiences can lead to situations in which generalizations of a more social nature can be gained by the entire class. When children's interests are respected and, whenever possible, related to the work of the entire class, then children are much more willing, anxious, and able to learn.

It is desirable that the children have a part in the selection of materials for the curriculum. This is a delicate operation. On the one hand, if the program is to have continuity and organization, it must have been planned long before the first day the children come to school. On the other hand, children are not passive pawns to be manipulated by teachers and made to fit into a prearranged program. In the science class this problem can be met most effectively by the teacher's having a large framework within which he is going to teach, and several possible plans and courses of action which fit into the framework. Then as he becomes aware of the children's interests and as he allows them to bring these interests into the classroom, he can adjust his over-all science program to allow for the ideas which come from the children. This gives real meaning to the curriculum both for the teacher and the children. The problems that are considered, the materials that are studied, the solutions that are found, all are more likely to be learned if the children recognize them as their own.

USING INTERESTS AT VARIOUS AGE LEVELS

There are a number of techniques which the teacher can use as he integrates the interests of the children into his over-all program. For example, at the kindergarten and first grade levels

the children are given opportunities to show their treasures to the group and tell about them. This has come to be known as the "show-and-tell" period. But by the time the children reach the third grade, this teaching device no longer serves and it should be replaced by a discussion period which considers children's interests and ideas. The teacher can use children's questions to determine some of their interests and subsequently find a place for these interests in the curriculum. Finally, the teacher often needs to stimulate new and wider interests in the children, and he may do this either by tossing a challenging question or problem to the group or by introducing some of his own interests and experiences into the program. Each of these techniques must be adapted to the particular teacher and to the needs of the group. The following descriptions show how these techniques may be used by teachers at varying grade levels.

SHOW-AND-TELL

During the early school experience of children, when they are very much interested in the immediate, when they are inclined to bring their possessions in to share with schoolmates, a very good teaching device is the "show-and-tell" period. The alert teacher who is interested in developing his science program can use these shared possessions to develop his program. This implies that the teacher has planned a curriculum that is likely to be in line with the interests which the children will have. Here is an example of one such situation in a first grade classroom.

It is early in November and Miss Rysack has been hard at work studying her group ever since school started. They seem to be ready now to tackle a science unit related to their needs and interests. The school program has been set up so that the first grade has five science units to cover, but the teacher may determine the order in which they are presented. These units are: fish

and how they live; seeds and how they grow; animals and their homes; toys and how they work; and electricity for doing jobs. Her choice of a unit developed as follows:

A few days ago Ted had brought in somo shells and had shown them during "show-and-tell" period. She noted that the children had been quite interested in the shells and that they played with them during their free time. She arranged a "directed show-and-tell" period by asking if other children had shells at home which they could bring to class. Susan and Jerry had some. Miss Rysack was deliberately structuring the period to concentrato the class's interest on "animals and their homes."

As the class settled down, Miss Rysack came directly to the point. "You remember the shells that Ted brought in a few days ago. Well, today I thought we might look at somo more shells. Jerry, do you have yours here? And how about yours, Susan? And you hring yours too, Ted." The three children pass their shells around tho group and Miss Rysack waits until most of the children have had a chance to see and examine them.

"How many of you know what these shells are?" The children have some mixed ideas about this question. Several children raise their hands. "These are sea shells." "When I was at the seashore last summer I found some shells on the heach." "I think they are like pretty stones." "I think that there are little animals that live in the shells." "But there aren't any animals in them now. Anyway, I can't see any animals. Are there animals in them now, Miss Rysack?" The children look more carefully at the shells and can find no signs of living creatures.

Now Miss Rysack introduces her own "show-and-tell" material and focuses the discussion with a leading question. "Have any of you looked at our aquarium recently? There is something in the aquarium which looks like these shells. Who knows what it is?

Yes, Judy?" "The snail." "Good, Judy. What does the snail do with his shell? Tommy, can you tell us?" "He carries it around on his back and sometimes he goes into it." "That's right, Tommy. Why do you suppose he does that?" Several of the children want to answer. "I guess it is like his house."

The interest of the children has been aroused. Susan, Jerry, and Ted agree to leave their shells on the "showing table" so that all may have further opportunities to examine them. In the course of the next several days a number of important things happen. Many children wander over to look at the shells. They examine them closely. A few children hold them to their ears to try to listen to them. They carry the shells over to the aquarium and compare them with the snail. Drawings of shells begin to appear in some of the pictures. Other children bring in shells. Finally, Susan arrives with a small turtle in a bowl of water. The time to capitalize on this growing interest has come. Miss Rysack decides to begin her unit on the study of "animals and their homes."

In addition to Susan's turtle, Miss Rysack has the snail from the aquarium. The group is brought together and the snail is passed around. The discussion starts: "That's his home, isn't it?" "Can he come out of that house and leave it and go back in?" "Does only one snail live in a shell, or do a mother snail and a father snail and all the baby snails live in the same house?" "What do snails eat?" The questions give many leads for the unit, and Miss Rysack carefully notes them for later use. But she wants to take the unit in certain directions so she introduces the turtle. She holds it up for the children to see and starts the discussion. "Did you ever see one of these?" Some of the children have, and as they pass the turtle around, she asks: "What kind of homes do turtles live in?" The discussion leads to a comparison of turtle shells and snail shells. Now Miss Rysack has her opening. She tells the children of her plans to find out how animals live and about animal homes. "Do you suppose that other animals have

homes? What kind of a home does a rabbit live in, or a squirrel? And what kind of a home does a bear live in?" Together, they plan for further study of the subject and end the lesson with the understanding that Miss Rysack will have a film for the next day about animal homes. Further, the children are asked to watch for animal homes on their way from school today and on their way to school tomorrow.

Miss Rysack has taken ioto account the children's interests and planned her program with this information very much in mind. But was she just lucky? Not at all. Suppose Ted had not brought in the shells. Suppose Susan had not brought in the turtle. Someone else might have brought in a bird's nest or a snake skin or something else that would have served the purpose just as well. But, if nothing had come, Miss Rysack still would have had several possible courses of action.

First, every teacher should recognize that he too is a member of the group. He can and should bring in things to show and share with the group. But this should be done in the spirit of the "show-and-tell" period. Just because the teacher has brought in the material, it must not be jammed down the throats of the children. The teacher would not allow something that a child had brought in to be forced in as the program for the class. If the teacher intends to introduce materials through such a period, he must treat his own materials with the same respect but also with the same cautions and restrictions which he would place oo the materials of any other member of the group.

Another kind of directed sharing would be ooe in which the class is takeo out oo ao exploration trip. For example, they might be takeo to a park or a field or a small woods or even only to the schoolyard. Their task would be to find materials from nature which could then be used for a class program. Thus, if oo child

brought in an animal home, Miss Rysack could have taken the children out to a place where they might find such homes.

Or, Miss Rysack could provide a topic for the period. Tuesday could be science day. The children can be encouraged to bring in materials in a given area and can then be helped to become articulate about such materials. Such structuring is more and more important as the children get older.

THE DISCUSSION PERIOD

As the children mature, the "show-and-tell" period no longer serves its function. The children, being more able to discuss and use abstract materials, are ready for intellectual activities of a different kind. They still meet for a sharing of interests, but these meetings now are more likely to take the form of intellectual discussions. Current events are important. Poetry and interesting prose which the children bring in also find a place in these discussions. Of course, science has a most important place.

The discussions cover a wide range. Sometimes, the talk goes to jets or artificial satellites or trips to outer space. Sometimes it revolves around personal problems like bedtime and how much sleep a child needs, or around foods and what you must eat to be healthy, or around bicycle riding and consequent safety rules. Sometimes it involves a natural phenomenon which has piqued the curiosity of a child. "Say, Mr. Oates, did you ever stick a ruler into a fish tank and then look at it? How come it looks like the ruler is broken?" Or, it might be, "Why do your cheeks get so red when you're out in the cold?" Or, again, "What are tides?" Many varied interests are apt to come up in the discussion period. The teacher must be aware of them and must be ready to use them in his program when they are appropriate.

Sometimes these interests can be considered summarily and then dropped. But sometimes they lead into a somewhat longer study. Mr. Oates teaches fourth grade. He has plans for a major unit on conservation. But a discussion period leads him to sidetrack his main unit temporarily. Here is a brief description of what happens.

"When we were flying out to Cincinnati to see my grandmother, it started to rain. But the pilot flew the plane up to where it wasn't raining." Jill brings this information to the group. Most of the children prick up their ears. "Go on, you're nuts. It can't be raining down close to the ground and be clear up higher." "It can too. I saw it." "It's not possible." "It is too. Isn't it, Mr. Oates?" The verbal battle rages and the interest in the problem becomes widespread. Most of the children are concerned enough to warrant spending some time on the problem of weather. So that is what Mr. Oates decides to do.

"You know," he says, "this is something that we can find out about. I think we ought to state clearly just what it is we want to know. Yes, Jill?" Jill is rather upset. Her word is being doubted. "I know that it happened. I saw it. And my father said that the pilot flew the plane up above the weather." Mr. Oates understands the situation and reassures Jill and the class. "Oh, we know that it happened. But the question is, how can it happen? It does seem strange, doesn't it? Maybe we can find out about it someplace. I have some books about weather and maybe we can talk to a pilot or to a weatherman and one of them can help us understand it. We can make a list of some of the questions which we would like to have answered. Then we can look up the answers, and we can also go out to the airport and talk with the experts there."

What kind of questions might these children ask? The list might be something like this:

1. Why does it rain?
2. How can it rain at one altitude and not at another?
3. How can water get up into the air if water is so heavy?
4. Can people make it rain or make it stop raining if they want to?
5. How high up do the clouds go?
6. Why are the clouds "dark?"
7. Why does the pilot fly the plane "above" the weather?

Mr. Oates is not going to make this into a long unit. At most he will spend five or six days on it. The subject, developed out of the interests of one child, fills a need for information expressed by the class as a whole. As an alert teacher, Mr. Oates recognized this interest and capitalized on it. After he has satisfied the needs of the children, he can go back to his major unit, having done two things. First, he helped the children with a real concern. Second, he used their expressed interests to help them build an informational background. Both of these are important general education and science objectives and, because of the intensity of the interest, the children are not apt to forget easily the weather information they have gathered.

It is incumbent upon the teacher to evaluate the interests that the children bring to school. Cursory interests need only cursory attention. A child who brings in a piece of slag and asks what it is does not want or need a long unit on mining and ore reduction. He just needs to know that this is a piece of slag. On the other hand, Jill and the rest of the class needed some more information. They could not be satisfied with a cursory answer of yes or no on the rain question. A few days spent on the subject, however, satisfied the needs of the class. Still other interests will be more lasting. They will fit into the curriculum which has been planned for the grade. Or, they will be of such

vital and sustained interest to the group that the previously planned unit may need to be replaced by one on the new material suggested by this interest.

In any event, it is the teacher who will need to decide how and when to use any given interest. He will need to evaluate the discussion of the group. He will need to see how often similar questions come up. He will need to determine whether one interest or another should be fostered. He will need to help individual children go on with their own interests if the class as a whole will not or cannot carry the interest as a part of the regular curriculum. Finally, be will need to make the decision as to whether or not to replace his previously planned unit with something that has grown out of interests which have been expressed in the classroom.

THE TEACHER'S ROLE IN DEVELOPING CHILDREN'S INTERESTS

Miss Rysack and Mr. Oates have watched their children carefully and have capitalized on the interests which the children brought to school. This is, of course, a prime function of the teacher. However, there are other functions which the teacher must perform in relation to the personal needs and interests of his children. In particular, the teacher should encourage the children to expand old interests and stimulate them to develop new interests.

In the stimulation of old interests, the whole tenor of the classroom is a key factor. This tone, this atmosphere, is the teacher's responsibility. The children will bring in their interests and concerns if the teacher has set a classroom situation in which personal interests and concerns play an important part in the over-all program. If children have opportunities to work on

their interests, their hobbies, their personal projects during the school day, then they will find this kind of activity socially acceptable and, consequently, personally acceptable. If children are allowed and encouraged to share their interests with the entire group, on the one hand they will be more ready to go on with individual studies, and on the other they will be introduced to new interests through their exposure to the interests of others. Furthermore, commending children for their interests and giving them recognition for the good work they do on their own is another important part of the teacher's job. Thus, one important aspect of a good science program is that the classroom, through the teacher's particular efforts, be "interest conscious."

Beyond the tone which he sets for his classroom, there is the factor of the teacher's own interests. The enthusiasm the teacher shows for his personal activities and the ways in which he brings his own interests and activities into the life of the classroom will be important in developing new interests in the children. The wider the range of the teacher's interests, the more likely he is to stimulate new interests in the children. Teachers cannot ride a single hobby, at least not as teachers. They must be interested in many things and must be ready to carry the children along with them in exploring these interests. Teachers must expect some of the children to out-distance them by carrying these interests to new levels beyond the teacher's own information. In fact, the teacher must encourage children to do just this.

Children like to identify with adults, especially those whom they admire and respect. In fact, this mechanism of identification is what makes many teachers so effective in the classroom. It is an important part of good teaching and the teacher who encourages such identification will have many children accompanying him on his explorations. The teacher who loves to build models can have some of the children building models

with him. The teacher who loves to knit can encourage children to knit with her. The teacher who has interests in sports will have an enthusiastic group of youngsters who will also develop an interest in sports. The teacher who is enthusiastic about exploring astronomy or geology or ornithology or rocketry or atomics or any other area of science will find that many of the youngsters will be eager to go along with him.

Finally, the teacher must challenge the children. He must dare them to explore new ideas. Carefully, thoughtfully, the teacher must whet the intellectual appetites of the children.

"I read in the paper that there isn't enough food for all the people in the world. I guess some people will have to starve. Do you think it ought to be the Americans? Or should it be the Russians? Or should it be the people of Africa? Or maybe there can be plenty of food so that everyone can have enough to eat? I wonder what we can find out about this?"

"Just what are the chances of people visiting other planets? Of course, some people have said that men could go and visit other planets, but what do you think, and why do you think it?"

"There is a real problem in our town. Our stream is polluted and we can't swim in it. Is there anything we can do about this? Just what are the facts? How can we get accurate information about this problem?"

"Just why does a satellite stay up in the sky? If I throw a ball up into the air, it falls down. Why doesn't a satellite fall to earth?"

"People say that if you find something that you like to eat, it is certain to be bad for you. Is it true that all "good" foods are either fattening or unhealthy or both? Just what is a proper diet for people who are eleven years old? How much and what kinds of foods should they eat?"

"I've heard that there are thousands of different kinds of but-

terflies in the world. I've seen a good many butterflies around here but I don't think I've seen more than four or five different kinds. I wonder just how many different kinds of butterflies there are in this area?"

Here are half a dozen challenges to a class, any one of which might start some of the children off on a new set of interests. Take the last one for example. How long would it be after a teacher presented this problem to his children before dozens of different specimens would be brought into the classroom? What would happen if he helped them make nets and the other necessary equipment for collecting and mounting butterflies? And then, if he took the children off on a field trip to collect specimens and used part of the school day to sort, arrange, and mount the specimens, he would be well on his way to starting many of the children along a new interest path.

Throwing out a challenge, however, has to be done carefully so that any projects that develop will have sufficiently diverse activities to utilize the talents of all of the children. Some children like activities of an artistic nature. Others want to read or to explore new ideas. Still others like to interview people. The good challenge will allow the children to answer it in a variety of ways. Not all people in a given class either can or should be made to do the same things at the same time. But the teacher must be certain that each child has a chance to investigate and learn new and worthwhile material. Thus, the challenge can be used effectively to stimulate interests and to implement the science program.

USING A CHALLENGE IN A FIFTH GRADE STUDY OF GRAVITY

Miss Elliot's curriculum includes a science unit for her fifth grade based on the interests that this age group displays in

the earth, the sun, and the universe. She especially wishes to capitalize on their expanding ability to work with abstract concepts.

It is discussion time. Various ideas have been of concern to the children for the past several weeks, but one of them keeps coming up for discussion again and again: the idea of space travel. Many of the children are beginning to read books on space and on related topics such as the planets, the stars, and the universe. Of course, the maturity and understanding of each child will be different, but Miss Elliot feels that there has been enough common experience among the group so that she can challenge them with a problem growing out of their discussions.

Miss Elliot has three objectives in science for the next few days. First, she wants the children to understand the several meanings of "gravity." Second, she wants to teach the children to "conceptualize" an experiment in science. Finally, she wants to explain the orbiting of the moon in the light of the two previous objectives. Here is her challenge and her lead into the science unit.

"Joe, you said that you and Jerry are going to be space pilots. But you need to know many things to be a pilot. All of you keep talking about space travel and satellites and flying to the moon and to Mars, but I wonder how much you know about those things. If I throw a ball up into the air, it falls down. Why doesn't a satellite fall to earth? What makes it stay up in the sky? Once it gets up into its orbit, it doesn't have a motor to drive it the way an airplane does. What keeps it up anyway?"

Her challenge is the introduction to the topic, "The Earth, the Sky, and Us." Starting with the development of the concept of gravity, she plans through reading, discussions, trips, experiments, and other teaching techniques, to have the children for-

mulate generalizations about the vast universe and their places in it. Here are brief descriptions of the first three lessons of this unit.

Children respond in varying ways to a challenge of the kind Miss Elliot used. Two of the boys start the discussion with these statements: "I don't know for sure what keeps the satellites up, but I know that gravity pulls the ball down when you throw it up in the air. Anyway, that's what everyone says." "Sure, gravity pulls everything down to the ground."

But Margie is not so sure. "If it pulls everything down, then *how come a satellite stays up?*" This, none of the children can answer, but Miss Elliot is ready. "I think I know some things we can try which will help us understand the problem. Janet will you please come up here? Now, Jan, first I want you to jump up in the air." Janet takes several jumps. Miss Elliot continues: "Did you all see that? Good. Now, the question is: Why does Janet keep coming down?" Several of the children again use the word *gravity* and offer it as the explanation. But Miss Elliot is not satisfied with the answer without further study of the word. "Will all of you get out your dictionaries? Let's look up gravity. Do you know how to spell it? Jud, you spell it and I'll write it on the board."

In a few minutes she had a number of children ready to give the various meanings of the word. From different members of the group, she elicits the information that the word has three meanings. As the children dictate, she writes the following definitions on the blackboard:

1. Gravity means an unseen force that pulls all things toward the center of the earth.
2. Gravity means a force that pulls all things together.
3. Gravity means seriousness.

First, she makes certain the children understand the meanings by having them use the word in sentences. She starts with the third meaning and gets the sentence: "The gravity of war is known to everyone." This meaning, she explains, is not related to the science they are studying, but she has the children note it for later use.

"What about the other two meanings?" With considerable help, the children come to understand that the first meaning, the one which explains that all things are drawn toward the center of the earth by gravity, can be explained best by saying that when Janet jumped into the air, she was drawn to earth by the *force* of gravity. In the same way, when a ball is thrown into the air, it is drawn to earth by the force of gravity.

The second meaning is much harder for the children to grasp. Miss Elliot tells them that the word gravity also is used to describe the force which draws *all* things together. She realizes that the children do not understand this meaning as yet, but she presents it to start further discussion. She explains it more fully by saying that gravity is the force which keeps the earth from getting further from the sun because gravity keeps the earth pulling on the sun and the sun pulling on the earth. It is also the force which keeps the moon from getting further from the earth. The moon pulls on the earth and the earth pulls on the moon.

"Yes, Margie?" "Miss Elliot, that's just what I meant before. If gravity is a force which pulls all things together, then why isn't the moon pulled into the earth? And why isn't the earth pulled into the sun? And why aren't all the planets and all the stars pulled to each other until they bang together?" "Yeah," says Judson, "that's just what I want to know. How do all the planets and the stars stay apart if they are all being pulled toward each other?" Eddie continues the questioning: "And

does that kind of gravity mean all things? Are people heing pulled toward each other? And books and desks and everything?"

Miss Elliot has begun to meet ber first objective. Tomorrow she will review the meaning of gravity with the class, but now she is ready to attack her other two objectives.

"These are all good questions. Let's get back to our experiment and see if we can find answers to them. Jaoet, will you please come up here again? Now Jan, you have had practice io jumping. This time I want you to jump up off the floor and stay up." The class breaks into laughter. "No," says Miss Elliot, "I am serious, I want Janet to figure out a way of gettiog up into the air aod not coming down."

A buzz of ideas starts around the group. "You mean stay up forever?" "Oh, you can't do that." "Do you need something special to do this experiment?" After a few minutes of open discussion, Miss Eliot restates the problem as follows "How can a person get up into the air and theo stay up as loog as he wants? You doo't need any special machioes or apparatus. Everything you oeed is right in this room."

"Now, Jan, do you have an experiment to show us?" "I don't know if it is an experiment, but I think I know how I can get up into the air and stay as long as I want." Janet gets her chair and sets it down in front of the class. Then she steps up onto the chair. "There," she says. Again the buzz starts. "She didn't do anything." "She isn't up in the air. She's on the chair." "Yes, but she is up higher than she was." "Heh, does that mean that the moon is standing on a chair?" "Go on, that doesn't prove anything." Miss Elliot brings the group back to the problem. "Let's do some thinking here. Remember what the problem was? How can a person get up into the air and then stay there as

long as he wants? Now, did Janet get up into the air?" The children agree that she has done so. Miss Elliot goes on. "Can she stay up as long as she wants?" Again the children agree. "Then Jan has found one way of solving the problem."

"Now, here is your assignment for tomorrow. First, make sure you know what gravity means. Then, I want you to see if you can find some other ways of solving the problem. You must try to find a way of getting up into the air and staying there as long as you want. Do you have any questions about the assignment? I'll put it on the blackboard so that we have it for our science period tomorrow." After she writes the assignment in a corner of the board, she dismisses the class for a short recess.

An analysis of this lesson brings out a very important teaching point. The word "gravity" is not an accurate term when applied to the force which draws all objects together. Miss Elliot in her study of the term found that in common usage it had both of the science meanings which the children gave. However, using the language of the scientist, only the first meaning should be given to the word "gravity." That is, gravity is the force which draws all bodies toward the center of the earth. The word which has the second meaning, the one which describes the force which draws all bodies together, is not "gravity" but "gravitation." However, these two words commonly are used interchangeably. Since the use of "gravity" for both meanings is not a serious error, Miss Elliot does not disrupt her program and take the children's minds from the major points she is trying to make. At the elementary school level, minutia and details can be avoided so that broad concepts can be established. Introducing and developing such details is a function of more advanced education. This will come more and more as the children progress through secondary school and college.

The second day's lesson takes up where the first one left off.

Miss Elliot starts with a review of the meanings of "gravity." When she is satisfied that the class understands the word, she is ready to go on. "Now, what about the homework? Have you found other ways of getting up into the air and staying there as long as you want? Yes, Jim?" Jim walks over to the closet door and opens it. Then he jumps up and catches hold of the door frame. He swings from it with his feet hanging in the air. He stays there for a few seconds and then drops to the floor. "If I were strong enough, I could hang up there as long as I wanted." This is the lead that Miss Elliot has been anticipating. She is going to help the children understand physical forces and she wants them to understand that Jim was using his body muscles to exert a force which opposed gravity.

"Why did Jim get tired?" When a good proportion of the children have an answer, she calls on one child. "Well, Carla, how would you explain it?" "I think he gets tired because he has to work to hold himself up." "That's right. His muscles are working to exert a force which holds his body up. Let's find some other examples of that."

From the children, Miss Elliot is able to gather information about several different situations in which opposing forces occur. They talk about a tug-of-war and, using first two children and then four, she helps them to see that in a tug-of-war opposing forces tend to balance each other. One child suggests that the engine of a train sets up a force which is strong enough to pull a whole string of heavy freight cars. Miss Elliot points out that the chair which Janet used exerted a force which kept Janet up in the air. Miss Elliot goes on. "I think we are beginning to understand. Let's see if we can state the solution of the problem?" After some discussion, the children agree on this statement: "To get into the air and stay as long as you want, there must be a force which is strong enough to overcome the force of gravity which pulls you to the earth."

Having settled this statement, Miss Elliot is ready to go on with the next part of her unit. Now the class is on the track which will lead to the study of planets, the sun, and the world of space. During the next day or two she plans to work with the children on some graphic experiences which will further clarify the meaning of gravity and will also introduce them to the concept of inertia. She gets a button and a heavy elastic band from her desk. As she fastens the button securely to the elastic band, she moves to a position at a safe distance but where all the children can see clearly. "I am going to swing this button around by the elastic band and I want you to watch what happens as it swings. First, I'll swing it slowly. Then I'll speed it up. Then I'll slow it down. Now watch carefully." As the button moves more and more rapidly, the circle which it makes gets larger and larger. As it slows down, the circle gets smaller and smaller. The slower the button travels, the smaller the circle in which it travels. When the button is spun with a constant speed, the radius of the circle remains constant.

Gradually, Miss Elliot draws all this information from the children. "Now what do you suppose there is that pulls the button in toward the center of the circle? That's right. It is the elastic band. And how about the force which makes it fly out farther? That is the force which my band gives to the button. When my hand gives it a greater force (spin), the button travels in a bigger circle. When the force is less, the circle is smaller. If it weren't for the friction of the air which keeps slowing it down, once I gave the button a start it would keep on going forever in the same size circle until something else stopped it. This is called *inertia.* About three hundred years ago, Sir Isaac Newton, a great English scientist, explained that this is the reason the moon keeps going around the earth. He said that the combination of the earth's gravitational pull and the moon's inertia keeps the moon in orbit."

Here is how Miss Elliot uses her third science period. "Today we are going to do our science in a different way. This way is one that many scientists use when they cannot really perform the experiment. They do it in their imaginations. It is different from the experiments that we have done before because for this we need no equipment at all. We'll just use our heads. We may use the blackboard too. We really don't need it, but it will help us keep things clear. Now let us work in our small groups. First, let's pretend that each group goes to a different place in the world. Let's see now. Jeff, suppose your group goes to San Francisco. And Margie, you take your group to Karachi, India. You, Jim, take your group to the South Pole." Miss Elliot settles on several different places around the world for each group to go in its imagination.

"Now the first thing that each group must do is to build a big tower. It must be very high. At least one hundred times as high as the Empire State Building. Yes, that would make it about twenty miles high. Oh, I know that we really can't do that. But remember what I said. This is a new kind of science work. It is a kind that we do in our imaginations and there such towers are possible. Has each group built its tower? Fine. Now suppose each group takes a ball—a good heavy one—and drops it out of the tower. Just drop it. Don't throw it. What happens to the ball? Yes, Jim?"

"It hits the ground at the bottom of the tower." "Do you all agree? Is that what happened all over the world? Did all the balls hit the ground next to the towers?" As the children indicate agreement, Miss Elliot goes on. "The next thing that I want each group to do is to throw the ball straight out from the tower. Don't throw it too hard. Just give it a good straight throw. Then I'd like each group to discuss among themselves what happened to the ball." When the children are ready to

report their decisions, she asks each group to appoint a secretary to draw on the blackboard the curved earth surface and the tower for his group. When this is done, each secretary is given some colored chalk and instructed to show what happened to the ball as it left the tower. Jeff draws a curved line from the top of the San Francisco tower to the ground. Jim has a bit of trouble. He is worried about what "down" means at the South Pole. However, everyone finally sees that falling "down" at the South Pole means what it means any place else on the earth. It means falling toward the center of the earth. The children's sketches look like these:

San Francisco *Karachi* *South Pole*

Miss Elliot continues the lesson. "Then we all found the same thing. When you threw the ball out straight, it curved off from the tower and fell to the earth away from the bottom of the tower." Again she gets general agreement. "Now take a cannon up to the top of the tower with you and shoot the ball straight out from the tower. What happens now? Will each secretary draw a line to show how the ball traveled when it was shot from the cannon?" The children draw sketches of the balls moving out from the towers and down to the earth's surface in wider arcs than before.

Miss Elliot makes sure all the children are following the experiment. "Well, is that what we all found? Did all the balls go further out but eventually land on the ground?" As the class

agrees, Miss Elliot asks an important question. "Why did the ball that was shot from the cannon fall further from the bottom of the tower than the one that you threw? That's right. The cannon shot the ball with a greater force. The ball traveled further out from the tower even though it was constantly falling to the earth."

"Fine. Now will each group fit its ball into a rocket? I want you to be able to shoot the ball straight out and you must have a tremendous force pushing it. All right. Let's fire our rockets. What happens to the rocket from the South Pole?" "We shot our ball up to Australia." "That's not bad for a start. How did the rocket work that was fired from Karachi?" "We landed ours in San Francisco." "Now you're getting there. Why don't you people at the South Pole give it another try? See where you can get this time." Jim pretends to fire the rocket. Then he says: "Hey! Did you see that? We hit the North Pole. Now we really are shooting." "Good," says Miss Elliot, "what do you think would happen if you gave it even more of a push?" As the children go on with their reasoning, she has them draw the trajectories of their various shots and finally there is a trajectory of one shot which takes the ball more than three quarters of the way around the earth.

"Now shoot it off still harder. What do you think will happen?" It becomes clear to the children that the ball should orbit around the earth. "Yes," says Miss Elliot. "When you shoot the ball hard enough, it keeps falling all the way around the earth." Next she leads the children to understand that if the ball were given a still greater velocity, it would spiral out further and further and further from the earth.

She goes on to tell the children that in order for the ball to orbit, the force must be large enough to keep it traveling at a little less than five miles per second. "At that speed, Jim's group could

come back from the South Pole in about half an hour. And Margie's group could get home from Karachi in about three quarters of an hour. That's very fast. You could go from Chicago to New York in three minutes and you could go from New York to San Francisco in nine or ten minutes." After clarifying the meaning of these great speeds, she goes on to tell them that to make the ball escape from the earth's gravitational field and fly off into space, the force must be large enough to give it a velocity of about seven miles per second. She also translates this velocity into terms that they can understand.

As the next step, Miss Elliot asks: "What would happen if something slowed down the ball while it was in flight?" It is clear to the children that under such circumstances, gravity quickly would pull the ball down. As the ball moves more slowly, the balance between its inertia and tho gravitational force changes. A discussion of what might possibly cause the ball to slow down elicits the fact that the friction of the air would he sufficient to do this.

"Why do you suppose the scientists don't orbit satellites at an altitude of only twenty miles? Let's see if we can find the reasons why they shoot them much higher than that." Together they work out the fact that air friction in the denser atmosphere of a lower altitude would bring the projectile down much sooner. Miss Elliot points out that still other factors affect the projectile —the gravitational forces of the sun, the planets, and the stars. She also points out that there are tremendous problems in building up a force which will send a projectile traveling at five or more miles per second. Having made these points clear to the children, she is ready to go on to the summary of the lesson.

The summary includes the following ideas:

1. If an object is dropped from a high place, it falls directly toward the center of the earth.

2. When an object is thrown straight out, it travels in an arc and is gradually pulled toward the center of the earth.

3. If an object is thrown hard enough so that it travels at about five miles per second, it will orbit around the earth.

4. If an object is thrown even harder, it will spiral out from the earth.

5. The friction of the air can slow down an orbiting object sufficiently to make it fall to the earth.

6. If the speed is greater than seven miles per second, the object will leave the earth's gravitational field and fly off into space.

7. The gravitational attraction of the sun, the planets, and the stars will also affect a satellite.

Miss Elliot can go on with her unit in many ways. She certainly will want to review and interrelate the experiments and discussions of the three lessons. She will want to discuss further the launching of man-made satellites. Of course, she will include the study of the orbiting of the moon and of the planets. She also has material for individual projects. Children will want to find the answers to such questions as:

1. What is the difference between a star and a planet?

2. How big are the planets and the stars?

3. What are the dimensions of the solar system?

4. What are the evidences of life on the other planets?

5. What are the problems of traveling to the other planets? To stars?

Of course, there will be the need for a well-planned culminating activity. Perhaps it will be a trip to a planetarium. Perhaps it will be a science-fiction play about space travel which the class writes and produces. Perhaps it will be an exhibit of drawings, models or reports of the work on astronomy. In any event, the

children will have a chance to sum up their experiences both so that they can clarify what they have done and so that Miss Elliot can evaluate the unit and determine how far she has taken them in their exploration of man's knowledge of the universe.

Summary

Children's interests are a necessary factor in the determination of the curriculum content. They are not, however, the exclusive factor. Other materials growing out of the demands of society must also be included in the curriculum.

There is an overlapping of the interests of children and the demands which society places upon the school. This is true because the children's interests grow out of the environments in which they live. While each child has individual and unique interests, there are sufficient common factors among these interests so that by studying the children and their communities, teachers can make sound plans for a science curriculum based upon what they can expect those common interests to be.

Before using an interest that the children voice, the teacher has the obligation to decide how widespread and how profound this interest may be. He may act in one of several ways. He may simply satisfy the interest quickly and go on with other work. He may make it the basis for a short unit. He may use it for an individual project for the interested child. Or, if the interest is wide and deep enough, he may develop it into a major unit.

The teacher also needs to crystalize the children's vague interests and, through his classroom work, create new interests in the children. In the former case, he needs to be aware of what the children are groping for in their questions and in their activities. In the latter case, he needs to help them by throwing out challenging questions and ideas to them and letting them carry these to logical conclusions.

V: Using children's interests

The teacher needs to realize that interests, while important materials for the school program, are also personal things. Each child needs to be encouraged to develop his own interests and to be given the opportunity to carry on these interests for himself.

VI USING REFERENCE MATERIALS

There is too much in our cultural heritage for each of us to learn, let alone learn from our own experiences. Three or four hundred years ago an educated man during the course of his life span could come to know most of the information that existed at that time. Some of the very great minds of the sixteenth and seventeenth centuries were not only aware of all of man's knowledge but were even experts in many of the fields of human endeavor. Da Vinci, Galileo, Newton, and Samuel Johnson could all talk and write as experts in many diverse areas. Da Vinci was as great a scientist and engineer as he was an artist. Even at the end of the eighteenth century, men like Franklin could be great scientists and writers as well as statesmen. Each of these men could try out the new ideas of his day. When Franklin heard of the experiments done with electricity, he did not just read about them; he tried them out. Through these experiences, he was able to add new knowledge to our ever increasing heritage.

But times have changed. What was considered special and advanced knowledge during the nineteenth century is now a part of the common knowledge of almost all high school students. After all, back in the early eighteen hundreds, geometry and algebra were college subjects. Arithmetic was the only required mathematics for admission to Harvard College until almost the middle of the nineteenth century. What was once the information and knowledge of only an educated few is now the curriculum of the elementary school. Because of the complexity of today's world, people now get a good share of their information through means other than their personal experiences.

The most obvious way of getting this information is reading. So many things that we need to know can be found in books and newspapers and periodicals that children should learn to use them effectively. Furthermore, there is another important reason why children need to use reference materials. In many instances, the materials and equipment for carrying out personal investigations of a given phenomenon are so specialized and costly that schools cannot have the equipment available. After all, an elementary school cannot have a radio telescope or an electron microscope for its children to use. And even if these instruments were available, the children could not learn to use them. But the children can cope with some of the information which specialists have gathered through the use of these instruments.

READING FOR INFORMATION

The problem, then, is to help the children find the most effective ways of gathering science information through their reading. Reading to gather information in science is really no different from reading to gather information in any other specialized field.

Just to review what is involved, consider the steps that must be taken to find special information:

First, the student must be definite about the information he is seeking. He should know what specific question or questions he is answering. He should know something about the field he is examining and some of the general terms under which the information might be listed. For instance, he will have trouble looking up information about star clusters under "nebulae" if he does not know that this term exists. And it would be equally difficult to find information about minute water animals without knowing such terms as "microorganisms" and "protozoa."

Second, he must know, in general, the sources from which he can gather his information. He needs to know what types of information he can find in dictionaries and in encyclopedias, other special reference books, newspapers and periodicals.

Third, he needs to know how to use reference books. He needs to know about indices and about tables of contents and about finding the special sections of reference books which bear upon the topics of his concern. He needs to be familiar with the card catalog and other guides to reading.

Finally, he needs to know how to read the special materials that are included in his topic. Are there special kinds of charts used in the materials which he is studying? Then, he should be helped to understand them. Are there special words which he will come upon over and over again? He should be helped with this special vocabulary.

Following these four steps can lead to some very important learning experiences. The teacher who is working with children in science can help them with reading skills. But it should be kept clearly in mind that reading skills are being taught so that the child can learn science, not the other way around. The reading skills are tools.

SCIENCE VOCABULARIES

The teacher's major responsibility as far as a science vocabulary goes is to help the children build clear concepts of what the words mean. Suppose a child comes across the word "crest" in a book about birds. There are several ways in which the teacher can help him. Perhaps the most important tool for reading science material is the dictionary. The teacher may have the child turn to this first. Of course, children start to use the dictionary very early in their school careers. The teacher, when be is teaching science, need only carry on what has been done with this skill *in other contexts. But carry on he should!*

The words of science are to be found in any standard dictionary. When any word has meanings other than its science meaning, the children should be encouraged to understand the various meanings of the word and to note particularly the science meaning. The word "crest" has several meanings, at least three of which can be related to science, but only one refers to birds. "Crest" can mean the top edge of a wave. Or it can mean the apex of a mountain ridge. Or it can mean the top feathers on a bird's head.

Meanings of words are understood by children as they experience what these words represent. As noted before, words, in order to have meaning, have to be brought into the experience range of the child. What about "crest"? The best thing would be to examine several birds and their crests. This can be done either in the classroom or in a museum or zoo. If this is not practical, pictures are second best. Helping children gain an understanding of the meanings of the science words that they find in their reading is an important part of every teacher's work.

Then, there is the matter of spelling. Many words in science have difficult and peculiar spellings. A child looking for the word "buoyant" in a dictionary is most likely to look under "boy..." Should the teacher who wishes to help the child find such a word necessarily tell him how the word is spelled? Not always. On the one hand, the teacher should not waste the child's time. It is much better to spell a word and go on from there than to spend a tremendous amount of time on a single word. However, the teacher must make the decision. Is it more important at the moment that the child figure out how to spell a given word? Or is it a more valuable uso of time to tell the child bow to spell the word and to go on to other things? Different situations will call for different actions. One thing is clear, though; the children can learn science words. Actually, many of the science words are easier for the children to learn than are the small words that they encounter over and over in their reading. Learning to recognize "dinosaur" or "elephant" or "generator" or any of the other big science words is much easier for children than learning the difference between "they" and "them."

Children need to be able to use the correct terms for the science experiences which they have. They can readily learn to call their instruments by their proper names and to recognize these names when they see them. The children will be able to say, to read, to understand "binocular microscope." They do not need to call it "the magnifying thing" or "the two-eyed microscope."

PRIMARY GRADES CHILDREN AND REFERENCE WORK

Children who are in the primary grades do not have the maturity or the necessary skills for reference work. But from the earliest school experiences on they should be aware that books can

furnish them with information to increase their store of knowledge and that a library has many varied and useful sources of information.

First graders will go to the library to ask the librarian for pictures of leaves or of kittens or of snowflakes or of dinosaurs that they can use in their classroom. Second graders will go for a book on goldfish or hamsters or magnets to help them with their science work. Even though many of these children have not yet mastered the skills necessary for the complete use of such books, they will be able to find pictures in the books which have bearing on the problems which are of concern to them, and the teacher can read some of the information to them. It is very important that *the children learn early about the many* sources of information from which they can draw.

As the children continue in the third grade, they approach a more formal use of the library for reference work. Now they will go to the library to find out what some book, other than their text, has to say on a given topic. Or, they may go to find the answer to a particular question that has been raised. At first, the children will read what the book says and give a brief oral report to the class. As the children become more proficient in the use of language skills, they should be encouraged to make brief written reports of their findings. First attempts are apt to be copied verbatim from the source, but, with a little guidance, children can learn to put the information they read into their own words. Reference work at this level has two goals. First, the children should realize that a library has much more information in it than can be found in a classroom; even though their own textbooks have some information on a given topic, there is much more to be found on the same topic in the library. Second, this information is found in varied resources: books, periodicals, pamphlets, maps, pictures, and the like.

REFERENCE WORK FOR INTERMEDIATE GRADES

In preparation for reference work in the intermediate grades, several important things need to be done. Doing reference work is a learned, not an inherited characteristic. Children have to be taught how to carry out this kind of activity. Clearly, they must be at an age when they are able to read for information. The science topic chosen for reference work should be one which can be studied best through the use of written material. The teacher must plan in detail the work that the children will do. This means that he knows what experiences the children have had with the library. Children who have had no previous experience with doing reference work will flounder and be lost unless they are properly introduced to the techniques. The teacher must know also what resources are available for the children, and with the help of the librarian he augments these resources if necessary. It is not enough for the teacher to pick a broad topic and assume that the children can do reference work on it. In his planning, the teacher must determine the following things:

1. Is the topic suitable for reference work? Can it be clearly defined for the children?
2. Are there sufficient and varied enough sub-topics for the children to look up?
3. Are there sufficient reference materials so that all the children will have materials with which to work?
4. Are the reference materials written in language which the children can read?

With this background, here is the beginning work of a fourth grade using reference materials in the study of animals.

A FOURTH GRADE STUDIES ANIMALS

Teaching a fourth grade class is an exciting experience. The children are very curious about everything around them. The world is their oyster, and they are ready and able to open it. Mrs. Handle's fourth grade is no different from others. For tho most part, these children have mastered the basic skills of reading, and books have npened new vistas for them. They want to know, to learn.

From time to time in the primary grades, they had experienees with the generalization, "There aro many kinds of living things and they are interdependent." In the first grade they had a pet hamster. They fed it and took caro of it. In tho second grade they had a tropical fish tank, and they watched the fish and snails and plants live together. They learned somo of the aspects of this science generalization through their own personal experienees.

Now they aro ready to go beyond the classroom and the immediate community. Children whn just a few short months ago did not know the difference between ten miles and a thousand, between the town in a neighboring state and a town in China, can now discuss, and discuss with understanding, events and places far from their nwn environments and from their own personal experiences. This is both an aid and a challenge to Mrs. Handle. On the one hand, the children can do so many moro things; they can study such new, interesting areas. But on the other hand, they need tn be helped tn develop this curiosity and to uso the newly learned techniques that they so proudly have brought into the intermediate grades. How much more science these children can work on now! This is the time for reference work.

Mrs. Handle has prepared a unit on the great varieties of animals that live around the world. She is concerned particularly that the children begin to learn about how living things adapt themselves to their environments. She planned her motivation carefully and put up an interesting bulletin board with pictures of several strange animals from different parts of the world. The bulletin board also has two challenging questions: Can you name these animals? Do you know where they live?

This unit is different from the other science units that the children have carried on because, of necessity, it involves reference work. Hamsters, fish tanks, and even small snakes can be brought into a classroom. But a panda or a kinkajou or a wallaby can come to the classroom only through the medium of books or through films and pictures. Furthermore, the habitat of these animals cannot be brought directly into the classroom. Now, of course, fourth grade children are not expert readers, let alone experts in the use of reference materials, and Mrs. Handle's youngsters are no exception. She realizes that it will be important for the children to develop their abilities in the use of reference materials. So, concomitant with her science goal (developing an understanding of how animals live around the world) is her goal of having the children learn techniques for doing reference work in the school library. She has prepared well for this reference work. With the assistance of Miss Goldsmith, the librarian, she has studied the materials available and has made necessary additions to the collection.

As she starts her science period, Mrs. Handle says: "How did you make out with the questions on the bulletin board? Do you know what those animals are and where they come from? Do you know this one?" She points to the panda. "Yes, George?" "That's a panda and it comes from China. I know because I saw it in my book about animals." "That's right, George. It is a panda and it does come from China. But I wonder if any of you

know in what kind of a place in China it lives? And what is a panda like? What does it eat? What kind of homes do pandas have?"

"I suppose that if we could, the best way for us to study about pandas would be for us to take a trip to China and go exploring in the mountains over there until we found some pandas. Then we could watch them and learn about them. And this animal is a wallaby. It comes from Australia. I suppose wo ought to take a trip down to Australia too and find some wallabies, but I'm afraid that some of your mothers and fathers would not let you have permission slips to go on such a long trip. So, since we can't go to those far off places, I guess wo will have to bring those places to us."

"How do you think we can get these places into our classroom?" This starts a lively discussion and the children decide that they can find out about the animals and places where they live from three sources: *museums, the zoo,* and *in books.* "Yes, we are going to do a new kind of studying. It is called reference work. In this kind of work we try to find out the things we want to know by looking in books. We'll find books and magazines and pictures about the places and animals in which we are interested. Then later, when wo have found out as much as we can about these things, we can take a trip to the museum or to the zoo and see some of the animals. Now, let's make our plans for this study. Just which animals should we study? And what do you think we ought to find out about them?" A list of animals is prepared and each child, with Mrs. Handle's guidance, chooses the one he is going to study. Then comes the next step, the "what" of the program.

"Now that we each have chosen the animals we are going to study, let's make a list of the things that we want to know about each of these animals. Remember to include something about

the places where they live as well as the information about the animals themselves. Yes, Jerry?" "We could find out what they eat." "What do you think, people? Is that something we want to know?" Mrs. Handle puts the question to the group. She is, by careful questioning and leadership, allowing the group to set up the reference problem. Of course, she, herself, will present some questions for the group to consider. Frequently children are not aware of many aspects of a problem, and one of the roles of the teacher is to present these aspects to them. Together, though, the group sets up the questions to be answered.

1. What does this animal look like? What color is it? How big is it? What kind of skin cover does it have?

2. Where—in what part of the world—does this animal live?

3. What kind of place is that? Is it a woods or a plain or a jungle or something else?

4. What kind of food does this animal eat? Does it eat grass or meat or fish or something else?

5. How does this animal get its food? Does it just find it growing? Or, does it have to catch its food?

6. How is this animal especially suited to live where it does? Does it have a special color so that it cannot be seen easily? Does it have a special coat or skin so that it can withstand the climate?

7. Does this animal make a special home for its babies? Is it a home in a tree or in a cave or in the ground or someplace else?

8. Is there something very special and interesting that you can find out about this animal so that you can tell it to the class? You might find a funny story about your animal. Or, you might tell about something special that this animal has or does that no other one has or does.

This careful definition of the problem is very important. The children know precisely what they are looking for and so the foundation has been laid for their reference work. They now can go on to the next step. Where does one look to find answers to such questions? Here is that part of the lesson.

"Now that we have the questions, how can we get the answers? Why don't we take one of the *animals* that no one chose? We can all study about that one together, and then you will know how to look up the answer to the questions about the animal you chose." She allows one of the children to make a choice and he suggests the cheetah. Except for the dictionary definition, there is no information about the cheetah in the classroom. So, they go to the library.

The entire class is gathered around a big table in the library. There are two sets of encyclopedias placed on the table so that all the children can see them. Miss Goldsmith takes over the class while Mrs. Handlo stays in the background to help when needed. Using reference materials will require that the children have experience with using the indices in books. Now, while this is a language skill and is taught in relation to the language arts, the children will need to make use of this skill in doing reference work in science, and practicing the skill is important to them.

"I understand that you are looking up information on the cheetah. Some of you have used these encyclopedias before. Which one of these books should we use? Of course, the one that has a 'C' on the back. Esther, will you find 'cheetah' in this volume?" Esther is given a copy of *The World Book*. "And, Jimmy, will you see if you can find 'cheetah' in this book?" Jimmy gets the "C" volume of *Compton's*. Esther soon has her reference, but Jimmy cannot find "cheetah." Miss Goldsmith knew that this would happen. The reference to "cheetah" in

Compton's is given under the heading of "leopard" and is in the "L" volume. She helps the class with this problem.

"You see, sometimes we cannot find what we are looking for in the encyclopedia where we think it ought to be. So, here, at the back of each book is an index. In *Compton's*, the index for each letter is at the back of the volume of that letter. All the 'C's' are in the back of the 'C' volume and all the 'D's' are at the back of the 'D' volume. Cheetah starts with a 'C' so look for it in the index of the 'C' volume. What does it say, Jimmy?" Jim reads: "Cheetah—Volume L, page 196." Miss Goldsmith continues: "That means that we will find the information on cheetahs in the volume marked 'L' on page 196. Will you get that volume, Jean, and see what you can find?" While Jean gets the "L" volume, Miss Goldsmith explains to the class that in some sets of books the index is found in the last book of the set. Then she goes on. "Let's hear what Esther has found. Read us what you have there, Esther." Esther reads the following material from *The World Book*:

> *Cheetah* or *Hunting Leopard*, is a large cat of the plains of Africa and Asia. It is three to four feet high, and has a small head and a long, full tail. The cheetah is yellowish in color, with black spots over all of its body except the throat. The body is so long and its legs are so slender that it is the fastest animal known for running short distances. Since the cheetah is so fast, it chases its prey. It does not crouch and steal up on its prey.
>
> The skin of the cheetah is used by some Africans to make clothes for their chiefs. The cheetah is tamed and trained for hunting in India. It is held by a leash and blindfolded until the game is seen. When the cheetah is freed, it makes a quick dash for the animal and holds it down until the hunters come.*

Esther also reads what appears under the picture of the cheetah:

The cheetah has blunt claws which cannot be drawn back into the paw like the sharp claws of other cats. The cheetah can be tamed and used for hunting game.

When the reading has been completed, Miss Goldsmith helps the children answer the questions. "Can we find out what the cheetah looks like? Does the book tell us about his color? Yes, Janet? That's right. The cheetah is yellow and has black spots all over him except on his neck. Do you see how we do this work? We take one of the questions and look for the answer in the material that is in the reference book. Now, the next question that you have on your list is about his size. Does the reference material tell us about the size of the cheetah? Jerry, can you find anything about the size of the cheetah in the encyclopedia?" Miss Goldsmith shows the children how to use the information they read and apply it to their study. She points out that while the encyclopedia gives a height for the cheetah (three to four feet), it gives no length. On the other hand, the article states that the cheetah has a very long body and a very long tail. From this, it can be concluded that the animal is probably more than four or five feet in length.

The answers to questions two and three can be found easily in the material. But questions four and five, the questions on the food that the cheetah eats, give Miss Goldsmith a chance to reteach the use of the dictionary. The article in the encyclopedia gives no direct information about the kind of food that the cheetah eats. But it does say, "Since the cheetah is so fast, it chases its prey." The word "prey" is new to the children. Miss Goldsmith has them look it up in a dictionary and points out that a dictionary has the function of giving quick, precise, and relatively simple information about a subject or word. Here is the definition of "prey" which they find: "an animal hunted or

seized for food: Mice and birds are the prey of cats." The children now can assume that the cheetah must chase and eat animals. The use of the dictionary is very important, and Miss Goldsmith makes a strong point of it with the children.

Questions six and seven also are very important in the lesson. The answer to neither of these questions is to be found in the material which Esther read from *The World Book*. The answer to question six, the one about environment, requires that the children do further reference work on the nature of the plains country of Africa and of India. The other question, the one about the kind of home this animal makes for its babies, requires further references also. Some of the children try to guess the answers to these two questions, but Miss Goldsmith helps the class understand that what they must do is find the answer in what is written and not just guess at it. The children find several interesting stories which they can tell in answer to the final question. Some want to tell of the cheetah as a hunting animal. Others want to tell about the use of the cheetah's skin for clothing for African chiefs. Still others think that it might be interesting to compare the cheetah with some of the other cats.

Now, Miss Goldsmith comes back to the questions which could not be answered from the information which the children read on cheetahs. The children suggest looking in the other encyclopedias. This they do, but they find that the other encyclopedias give them little more than they found originally. "What do you think we ought to do now?" asks Miss Goldsmith. With some careful questioning, she guides the children to seek further information in special books on animals. Books about animals around the world, about animal homes, about how animals care for their young, etc., are all available. Many of them are well written children's books. Some of them are adult books, but the better readers can cope with these. From such books the children can obtain the answers to the remaining questions.

"I understand that each of you has selected an animal to study. Suppose we just list the steps that you must take in order to do your reference work." The group working together makes up the following list:

1. Make a list of the questions that you would like to have answered.

2. Look up the topic in an encyclopedia and study the information which you find.

3. Try to answer as many of the questions on your list as you can from the information which is given.

4. Look up the words you do not understand in a dictionary.

5. Questions which are not answered by one encyclopedia can sometimes be answered by the material in another.

6. Questions that cannot be answered by using the encyclopedias often can be answered by looking in special books or other printed matter on the topic you are studying.

This list of techniques for using reference materials is sufficient to serve the needs of the children in the intermediate grades. Using these suggestions, Mrs. Handle's children are able, to a *greater or lesser extent depending on the ability of the individual* child, to go ahead with their studies of animals. Of course, both Mrs. Handle and Miss Goldsmith help each child as he needs help. The slower readers are guided to simpler materials. The faster children are steered towards those materials which can challenge them.

The above experiences have been telescoped. In introducing any new study, the teacher necessarily sets a pace deliberately fitted to the needs of the group. The lessons which have been described may take three days or a week or even two weeks. Learning to use these reference materials takes time. Don't rush!

A SIXTH GRADE STUDIES THE ICE AGE

As children have the opportunities to explore problems through the use of reference materials, they become more and more proficient in the use of these materials. Just as with other skills, they can add more complex techniques to their reference work as they mature. In particular, they can be helped to set up their own reference problems. And they can be helped to use all the facilities which a library offers to those who need to find information. They can learn to use the card catalogs. They can learn the use of cross referencing to extend their field of study. In brief, they can learn important basic techniques in using reference materials that they will need to use for the rest of their school careers, and that some of them will need for the rest of their lives.

The development of reference problems for a sixth grade will take the teacher and the class through many of the same procedures that were used with the fourth grade. Certainly, the teacher will need to examine the facilities of the library in the areas where the research is to be done. Of course, the children will need to be properly motivated. And a review of the library techniques already learned by them is quite necessary. Again, it is very important to remember that the purpose of this reference work is to learn some science, in this case to work on the generalization, "The earth's story, its history and current condition, can be read from its rocks, soil, and waters." The reference work only helps the children move towards the goal of understanding this generalization. Mr. Jennings is working with his sixth grade. See how he goes about it.

"I want Anita's committee to go up to the library now. Mrs. Taylor is expecting you. She is going to help you find materials from which you will be able to get the answers to the questions

that we asked about the Ice Age. Don't forget to take your lists of questions. And, don't forget your notebooks and pencils."

Six children, carefully selected so that they can work together and can profit from the special instruction which Mrs. Taylor and Mr. Jennings have planned for them, leave for the library. Each of them has a list of questions which has been prepared jointly by the committee and Mr. Jennings. This committee is working on "The duration of the Ice Age and its various advances and recessions." They have questions like these to answer:

1. How do scientists know that there was an Ice Age?
2. How have they been able to date the beginning and end of the Ice Age?
3. How do they know that there were several advances and recessions of the glaciers?
4. What conditions existed in North America during an ice advance?
5. What conditions existed in North America during an ice recession?
6. Were the advances and recessions taking place at the same time all over the world?

Anita's group is a very capable group. They are going to be able to do more advanced work than the rest of the class. By the sixth grade, there are wide divergences in the abilities of the children to work with abstractions. Mr. Jennings has planned for these divergences, and this group will receive help on the level at which they are capable of working. They will use many books and material of an advanced level.

Mrs. Taylor is waiting for the group. She has cleared this period completely to work with the children because she is anxious to help them learn how to use the library more fully. There

is nothing quite so frustrating as to look for something in a library and not to be able to find what you need. She will go over library resources with each group of children carefully and will give each group as much help and as many techniques as the group is ready and able to use.

Mrs Taylor has the six children sit down around one of the library tables so that they can discuss their problems. It is important to keep the size of the groups small so that each child can have an opportunity to work with the reference materials. "I understand that you are working on the Ice Age. Now, where will you look first for materials? The encyclopedia is a good starting place, but for you, it is only the start. Where will you look after that?" From the group, she receives the suggestion that they can find a bibliography at the end of the encyclopedia article.

"And, what do you do with that list of books?" Now the children are referred to the card catalog. Of course, these children have had previous experiences with the card catalog, but they review the fact that there are three headings under which material can be found: Author, Title, and Subject. "You can look up these books in the catalog and see which of them we have in the library. You know that when you find the card for a book you can copy down the call number and then, using the number, you can find the book on the shelves. Mrs. Taylor gets out some of the file cards and reviews for them the information that they will find on the cards. The catalog contains either simple cards which she has typed herself or the H. W. Wilson Company printed catalog cards for children's books. She also points out where the science books, the "500's," are kept in the library.

"After you have found these books, where will you look for further information?" Here, Mrs. Taylor is after two things. First,

she elicits from the children the fact that they can use pamphlets, the picture file, almanacs, atlases, and current science magazines. But, even more important, she gets them working on cross-referencing to expand their search. "The thing you need to do now is to find other headings to trace. Your topic is 'The Ice Age.' After you have looked that up in all the possible sources, what other subjects should you look for?" Together, the children make a list of possible headings relating to their topic. Here is their list:

Cave Men	Glacier National Park
Iceberg	Prehistoric Animals
Iceland	Alaska
Geology	Antarctica
Glacier	International Geophysical Year

"Now that is quite a list. But if you want to add to the list, where can you get some other ideas? Yes, that's right. You can get some further ideas from the articles in the encyclopedias. But, did you know that you also can get some cross-reference ideas from the cards in the card catalog?" Mrs. Taylor shows the children some of the cross-reference and tracing words on one of the cards.

With the completion of this discussion, Mrs. Taylor has the children go to work on finding the answers to their questions. As the children use the various materials, she watches and helps them. Some are steered to more difficult materials, some to simpler things. Some are simply asked a leading question or two, some need to be shown specifically how to find the particular book which can give them certain information. Each child, though, is able to go ahead at his own rate and each is able to solve his own problems.

Mr. Jennings, meanwhile, has been working with the other children. They, too, will come to the library to use reference

material and will have the same kind of experiences as Anita's group. Each group will receive the special help that it needs. The less able children will be given more review, more time to work with simpler materials. The specific topics assigned will also reflect the varied interests and abilities of the children. Some will work with simple children's books, some with adult encyclopedias and geology texts. All, however, will do reference work. All will report on their findings. These reports will come in the form of pictures, in the form of oral statements to the class, in the form of written materials. And, Mr. Jennings will insist on knowing the sources of information: "Barbara, where did you find out about those cave dwellers? No, it's not enough just to say that you found it in the encyclopedia. We must know which encyclopedia." And, "Martin, you must know which book told about the mammoths. Because there are so many different sources of information and they all don't agree, we need to tell where our information comes from."

Summary

Using reference materials is the first step in developing research techniques with children. Research will be an important tool for these children. It will combine what they have learned about gaining information from authorities with what they have learned about setting up problems, establishing tentative hypotheses, testing their hypotheses with experiments and drawing valid conclusions.

But reference work will have validity in and of itself. As the children become concerned with and interested in the wider world which they cannot reach through firsthand experiences, they will want to work with books and with other reference resources. As these children come to the important intermediate grades period—the time when they are so anxious and willing to learn new things—reference work will be very satisfying and valuable to them.

Finally, teachers must remember that reading, whether it be from an encyclopedia or from a book of any other kind, is a tool. It is the concepts the child learns that are important. The skills which are gained while learning these concepts are all to the good. But, eventually, what must come from science lessons which involve the use of library skills is a knowledge of the science concepts that are being studied.

VII MEASUREMENT AND QUANTITATIVE CONCEPTS

SOME teachers may argue that the old fashioned education had some real advantages. At least the children did not ask impossible questions. Not out loud, anyway. But these days, you never can tell what children may ask. "What makes the leaves change color?" "How big is an atom?" "How many stars are there in the sky?" "How far away is the sun?" And, worst of all, "How do you know?"

Answering questions for children is one part of a teacher's business. As we said before, it is very important that children find out how to answer questions for themselves, but sometimes their questions must be answered directly. Teachers can respond in many ways to the questions that children ask. Of course, they can squelch the children. If children are made uncomfortable enough when they ask questions, soon they will ask no more. Or their questions can be evaded, but children soon see through this sham, and what they learn from this kind

of response is the dubious art of deceit. Or teachers can answer questions with very special and practical responses. To the question, "How far away is the sun?" they can answer, "93,000,000 miles." And to the further question, "How do you know?" they can say, "I read it in a book." Such replies give out information without helping children to find answers for themselves. Make no mistake about it, sometimes all that is wanted and needed is specific information. Sometimes the important thing to do is just give out the information. Sometimes it is the only thing to do. Sometimes it is the best thing at the moment because there are other immediate goals to be attained.

Suppose, however, that the teacher wants to help the children work out some new concepts. Suppose that he wants to help them build up new ideas about their world. One of the areas that must be worked on is that of quantitative thinking. So much of the modern world can be understood only in terms of quantity and its related ideas that teachers must help children with these concepts—quantity, interrelationships, and dependence.

THE EVOLUTION OF QUANTITATIVE IDEAS

"Ontogeny recapitulates phylogeny" is an old scientific adage. The development of quantitative ideas and concepts in a child might be understood better if the development of some of these concepts in mankind was examined. Of course, no one can be sure, but this is what probably happened.

As civilized man came to be, he faced very practical problems. He needed to count and to measure. He needed to survey and to build. Anthropological findings indicate that early men did these things very well indeed. The people of Babylon had a number system which served them well even in the most com-

plicated accounting. The people of ancient Egypt measured and built the most complex buildings with an accuracy that would put many modern builders to shame. The base lines of the Great Pyramid are off by less than an inch in a total length of 755¾ feet. That is some engineering!

But these people were keeping books and erecting buildings. They could work with *things* like "15 goats" or "triangular fields," but they could not work with *ideas* like "fifteen-ness" or "triangles." The first records that have been found of work with "ideas" come from the ancient Greeks. Thales of Miletes and his followers, Pythagoras and his disciples, and Aristotle, over the course of several hundred years, brought us to the beginnings of what is called science, when they led us into the area of the abstract. Instead of studying numbers as related to things, they studied the concepts of the numbers themselves. Instead of studying triangles as related to fields, they studied the abstract notion of the triangle itself. Then, when they went back to a study of the actual field, they could bring to bear on their study all of the information of a general character which they had discovered.

QUANTITATIVE IDEAS FOR CHILDREN

This, then is the course that needs to be followed with children. They need to be helped to pull from their daily and common experiences those areas which can be idealized. They then need to be helped to generalize from these ideas. Finally, they need to be helped to take their generalized ideas back to real situations to increase their understanding of the world.

There are three distinct areas into which quantitative ideas fall. First, there is numeration. Since the first cave men counted, since our primitive ancestors started using sticks and pebbles

and fingers for such activities, men have been enumerating their offspring, their possessions, and their problems. This task still faces man today. But now he can use the tools which have been developed over the centuries and by many different peoples. Today, what is called the Arabic Number System—the one which we use and take so much for granted—is the *basic counting* tool. It is such a wonderful and useful tool! Children must be helped to understand it, to appreciate what it can do for them, and to use it well.

The next area is that of interrelatedness and dependency. The relationships of natural and of man-made phenomena are expressed in many ways. But the tool that has been developed and used over the past several centuries which best satisfies man's need to express and understand interrelated ideas is algebra. Be careful not to bridle. Truly, algebra *is* a simple and easily comprehended subject. You can make sense out of it, and children can be taught to do so too. Algebra can express, in a few symbols, many very long and complex ideas. Look at just one simple example:

$$A=\frac{1}{2}bh$$

This simple statement replaces the following paragraph:

To find the number of square units contained in an enclosed figure which has three sides, multiply the number of units of length of one of the edges by the number of units of length in the line drawn perpendicular to that edge from the corner opposite that edge and then take half of the product thus obtained. The result of this arithmetic process will always be the square units contained in the figure, or its *area*.

Quite a statement, isn't it? Yet that is what the simple formula says. And that is what formulas or mathematical statements of relationships can do. They can be used to express, simply and clearly, what cannot be said as well in hundreds of words.

They can be used to show the relationships which exist between weight and cost; between time traveled, rate of speed, and distance covered; between area, length, and width; between energy, mass, and the speed of light; between two or more interdependent variables. Children must be helped to see how this tool can serve everyone in an understanding of this complicated and interdependent world.

Finally, there is the idea of size. For this, the science of measurement, including geometry, has been developed. There are so many impressive concepts here, and so many fascinating instruments to learn about and use! There are, of course, rulers, scales, and protractors. But there are also other measuring devices: thermometers, barometers, wind gauges, micrometers, revolution counters, and dozens of other devices for making comparisons of what needs to be measured with some known standard. And as this measuring is done, children can go from what is common in their experiences to what is far from them. They must learn to comprehend the very small and the very large. First, they learn one inch or one yard or one pound or one ounce. Then, they can go off both in the direction of one mile, one ton, and even one light year, or in the direction of one grain, one microgram, and even one angstrom.

LEARNING QUANTITATIVE CONCEPTS THROUGH UNDERSTANDING

These abstract quantitative ideas have been the nemesis of many a student. Over and over, mathematics and science have been cited as the causes of school difficulty, the hated areas of study, the reasons for dropping out of school. Furthermore, high school and college teachers tell us that many students who come to them are unable to function in these areas. The levels at which people function in science and mathematics will vary from individual to individual. But more people could become adept in

the use of abstract materials if they had better learning experiences from their earliest formal education on.

In arithmetic, a child who studies about how to find an area by working out so-called problems with the formulas he has memorized knows little of the meaning of "area." He is not likely to understand that to measure an area means to find the number of squares of a certain size found on its surface. But the child who uses area for practical problems—for buying screening for a cage, for measuring a surface for paint, for fitting materials onto a sheet of paper, or for making a dog house or building a boat—is much more ready to accept generalizations on special relationships. From the everyday, the practical, the specific, to *generalizations, to conception—that is the way children learn* most readily.

Or consider a simple problem like this:

$$\begin{array}{r} 324 \\ \times 26 \\ \hline 1944 \\ 648 \\ \hline 8424 \end{array}$$

Most people can do this problem easily. They "learned" the formula for doing it at about the fourth grade level. But there are few who can explain what they do. Exactly what is done in such a problem? First, what is the problem? It asks the question: "If three hundred twenty-four is taken twenty-six times, what is the resultant sum?" There are several ways of finding the answer. *For example, this could be done by the continuous addition of* ones until enough of them had been added together to make twenty-six "324's." A shorter but slightly more difficult way would be to add by fives. Even shorter would be to add by tens or possibly hundreds. This is what the Roman systems did and what many modern systems such as the Japanese and Chinese systems

still do. But these systems are quite cumbersome and difficult to use with large numbers. The answer to this same problem in Roman numerals is:

$\overline{\text{V}}\text{MMMCDXXIV}$

And, getting this answer is tedious, to say the least. But the invention of the Arabic decimal system made this kind of problem easy enough for fourth graders. The rules of the system are simple. The combinations can be memorized, especially if the student has good reasons for such memorizing. Using these rules, the original problem becomes three simpler problems. It becomes:

1. 324 times 6
2. 324 times 20
3. The sum of the answers to the two previous problems.

The first part of the problem is:

$$\begin{array}{r} 324 \\ \text{X}6 \\ \hline 1944 \end{array}$$

Why? How does it happen that the numbers are written in this order? Analysis shows that what has been done is to put the rules of the decimal system to work.

According to the decimal system, 324 is three *hundreds*, two *tens*, and four *ones*. Thus, rewriting the problem with lines to separate the digits, we have the following:

thousands	*hundreds*	*tens*	*ones*
	3	2	4
		X	6

The first step is six times four *ones*, which makes twenty-four *ones*. But, again, according to the rules, twenty-four is two *tens* and *four* ones:

thousands	*hundreds*	*tens*	*ones*
			4
		X	6
		2	4

	thou-sands	*hun-dreds*	*tens*	*ones*
The next step shows that six times two *tens* makes twelve *tens*. This is one *hundred* and two *tens*. Putting these into their proper places produces:			2	4
			×	6
			2	4
		1	2	
		3	2	4
Finally, six times three *hundreds* gives eighteen *hundreds*, or one *thousand* and eight *hundreds*. Now the problem looks like this:			×	6
			2	4
		1	2	
	1	8		
Adding these together, we get one thousand, nine *hundreds,* four *tens,* and four *ones:*	1	9	4	4
In the same way, doing the second part of the problem (324 times 20) yields six *thousands,* four *hundreds,* and eight *tens.* There are no *ones:*	+6	4	8	
Adding shows a total of seven *thousands,* thirteen *hundreds,* twelve *tens,* and four *ones.* Using the rules of combination again we change this to the usual answer: eight *thousands,* four *hundreds,* two *tens,* and four *ones:*	8	4	2	4

It takes long to explain the problem this way. It requires patience and understanding to develop such ideas with children. But it is worth the effort. It explains an abstract concept. It makes for true learning, the kind of learning that is not easily forgotten. This is the kind of reorientation to mathematical ideas which elementary school teachers must make. First, the teachers must do it for themselves. Then, they should do it with their students. *It is a job that can and must be done.*

PRINCIPLES OF LEARNING RELATED TO QUANTITATIVE IDEAS

Let us now examine some of the problems involved in this kind of teaching and some of the techniques for helping children develop these quantitative ideas.

Effective teaching comes from an awareness and understanding of what is to be taught. Perhaps the most important reason why it has been difficult to teach quantitative measurement to children is that few teachers have gone at the task rationally. They have not set up systematic plans and carried them through logically over a long period of time. Here are some of the basic principles which a teacher must understand if he is to be able to help children learn abstractions of a quantitative nature:

1. People generally, and children especially, learn within the context of their previous experiences. New things are learned by building them into a previous set of experiences. The meaning of "five" comes as five is used in living—five fingers, five cents, five children, five anything, and then "fiveness." The abstract concept "five" comes after many concrete experiences with groups of five items.

2. Children develop concepts from what they have seen or felt or heard—in other words, *concepts are developed from percepts.* This is especially true with abstractions like quantitative ideas. Once the learner has a thorough understanding of a number of percepts, once he has truly sensed their meanings, then he can be helped to generalize them into sound, usable, concepts. He generalizes from his experiences.

3. Learning is more effective when the learner is able to grasp the relationships among the various elements in the problem situation. Children need to be helped to see whole situations and the various parts in relation to the whole.

4. Good teaching requires that each learner be given a chance to understand clearly each of the items that will help him

build his concepts. He must have a chance to have as many sensory experiences as possible with each of these items. He must see the item, hear it spoken of, speak of it, touch it, even smell it if that is possible. The wider the variety of sensory experiences with an item, the more likely he is to learn it. Thus, learning "fiveness" means seeing five things, bearing about five things, touching five things, talking about five things. It means, in short, many experiences with "fiveness."

5. Learning is facilitated by many factors. First, must come the experiences—many of them which use all the senses. But then comes practice. Children cannot be expected to really understand "fiveness" merely by having arithmetic combinations to do. But—and this is very important—if they are to use arithmetic combinations effectively and easily in their work with more complex problems, they must practice these combinations. And they must practice them even after they have learned them. Overlearning, not to the point of boredom, but overlearning itself makes for greater retention of facts.

6. Practice makes much better sense and learning is much sounder and more thorough when it is related to things the learner wants and needs to know. Thus, *practice does not need to be dull. It can be a challenge.* Learning to do averages can be simply dull rote, or it can be a necessary part of solving an important problem that concerns the learner.

These principles must pervade all teaching, but especially the teaching of abstract, quantitative concepts. There must be no haphazard approach to the teaching of such ideas. Of course, we must take advantage of the incidental and fortunate events that lead to their further development. But two things should be noted:

1. These "fortunate" incidents are more likely to occur when they are planned for.

2. Teachers will be much more aware of such incidental events and much more ready to take advantage of them if they plan their over-all programs with these problems in mind.

MEASURING IN THE FIRST GRADE

Mathematics is an all day, every day subject. It is all around us all the time. What should the teacher do when, as it inevitably must, the following sort of incident occurs? It is ten-thirty and time for the first grade to go outdoors to the playground. The long winter months are coming to an end. Yesterday was a pleasant day, but rather cold. Today, it is quite warm. Baseball and jump rope are in order. But how can you jump rope or play baseball with snow pants on? "Miss Warren, do we have to wear snow pants today?"

What are the possibilities? First, of course, the teacher can say that everyone must wear everything he wore to school. If mother sent you with snow pants, then you wear snow pants. Or she can say that no one must wear snow pants. When the pressure is great and there is no objective way of determining policy, the teacher may submit to this personal pressure. But there is another way. It depends on the answer to the question: "Why should we wear snow pants?" We wear them to protect ourselves from cold. And we have a way of knowing if it is cold outside. We have a measuring device for determining how cold or warm it is. Of course, it is a thermometer.

Let's put the thing very simply. If the thermometer reads about fifty degrees (or whatever arbitrary value has been established), then the children may go without snow pants. If it is lower than that, then snow pants are worn. No fuss. No muss. No arguing. Of course, it means having an outdoor thermometer hanging outside the classroom window where all the children can read it. It means drawing a red line at the fifty degree mark so that no child is left out of the process of finding out what the temperature is. Obviously, temperature does not necessarily have to be measured in degrees. There are grosser measurements too. In this case, there are "snow pants" temperatures and "no snow pants" tem-

peratures. As the children mature, they will have to refine their measuring and measurements, but for the present they are using simple comparisons.

There are many such comparisons to be made: bigger and smaller; in front of and behind; heavier and lighter; before lunch and after lunch; further and nearer. And of course there are the comparatives: small, smaller, and smallest; far, further, and furthest; late, later, and latest—these are quantitative ideas. They depend on the arbitrary selection of some standard and the measurement of all other similar ideas in relation to this standard. Working with these kinds of ideas, planning for their inclusion in the curriculum, making work sheets which stress these comparative concepts, finding all of the incidents which involve "measuring"—these are part of the elementary teacher's responsibilities. They are the beginnings of "geometry" and of "algebra."

There are various measuring activities for primary grades. Measuring heights and weights, keeping temperature recordings for an aquarium, incubating chick eggs and checking the temperature for the twenty-one days, comparing weights by the use of a simple balance, comparing lengths, comparing areas—all are experiences which children in the primary grades can use profitably.

Next, there are all the activities involving numeration. This goes on in the classroom constantly. For example, "Eddie, will you count the people who are here today? We need to take the attendance. And while Eddie is doing that, Sarah and John can collect the milk tickets and find out how many containers we need today." Of course, it is easier for the teacher to take the attendance and the milk count herself. She will have to do it anyway because she must have an accurate check. But it is a good teaching device and a good learning experience for the children to do this. Furthermore, it is surprising how accurate the children can be.

This aspect of counting will also come up over and over again in science work. The group will want to count the number of seeds that are planted and the number of seedlings that germinate. They will want to count the variety of trees on the school grounds and make an exhibit of the leaves, barks, and fruits of these trees. Other exhibits (shells, rocks, woods, flowers, etc.) will all need to be numbered and identified. If the teacher does not help the children make a catalog of these exhibits, a fine opportunity for work with numbers, with language arts, and with graphic arts will be lost.

The thing to remember is that counting and enumeration are important activities in the primary classroom, not only for mathematics, but also as essential parts of all work and especially of science. For example, a first grade can make a weather chart—a chart which shows rainy days and sunny days and cloudy days—like this:

October						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

This is science. It is a study of weather at the first grade level. But at least as important as the study of different kinds of weather is the recording of the number of each of these different kinds of days.

THERE WERE:
11 SUNNY DAYS
14 CLOUDY DAYS
6 RAINY DAYS,
IN OCTOBER.

This is an activity chart which includes numbers that come from the experiences of the children. It is important for the teacher to continually provide for these experiences.

The children study about the total number of items in a collection. They talk about the number of different kinds of items. They count the number of each of the kinds they have. They talk about the fifth or the eleventh or the twenty-sixth. The teacher works with the children on establishing a "one-to-one" correspondence between the item and its description. Numbers become an important part of each task in which they have meaning.

Ours is a quantitative civilization and teachers must take this into account as they work with children. All through school stress should be placed on counting and measuring. This should be done in the regular work in arithmetic. But also, teachers should work on the establishment and understanding of quantitative ideas wherever and whenever they arise. In order to learn how to use abstract concepts, children must first understand them; then, by using the concepts in a variety of ways and many times over, they fix them. This is the pattern which should be followed continuously, from kindergarten all through school.

STARS FOR THE SIXTH GRADE

But what about science that directly involves quantity for its explanation? Material in such areas as astronomy or geology

cannot be clear without mathematics, without an understanding of the vastness of time and of space. How may such quantitative concepts be developed? Here is a sixth grade working on a unit about the earth, the other planets, the sun, and the stars.

The room is all astir with business. Mr. Golden is moving from group to group, helping where needed. The first group of four children is working on a chart. It looks like this:

FACTS ABOUT THE SOLAR SYSTEM

Name of planet	*Diameter*	*Distance from sun*	*Period of revolution*	*Period of rotation*	*Number of moons*
Mercury					
Venus					
Earth					
Mars					
Jupiter					
Saturn					
Uranus					
Neptune					
Pluto					

The children have made the chart, they have decided on the information which they are including, and they are now searching for this information. Ted explains: "We are the committee on the Solar System. We are collecting facts from reference books and are making ditto sheets for the class so that everyone can have this information too. Then we are going to build a model of the

Solar System and hang it up in the room. We are going to make the sun out of a big yellow balloon and the planets out of smaller balloons." Jimmy is the little, excitable one. He explodes: "And we are going to the museum for a trip and we are going to see the planetarium they have there and . . ." Ted interrupts calmly: "We are trying to figure out a way to show the orbits of the planets, too. We think we will put up big circles of crepe paper around the room. I guess that will work if we hang the circles with enough strings."

A small group in a corner of the room is preparing a report on theories of how the Solar System originated. They are using film strips and are also making slides to use in their report. Off by themselves, two boys are reading books on astronomy.

Here is a group of six children. Each of them has a sheet of paper on which there are lines and markings. These are their first trial sheets for determining "solar noon." One of the boys explains: "You see these lines are the shadows made by a pencil on this sheet of paper. The numbers there are the times when the shadows were made. We started at eleven A.M. and stopped at one P.M., and we marked the shadows every five minutes. My shortest one seems to be at 12:16 P.M. We have six sets of shadows which different people have measured. Now we will find the average of all of the times for the shortest shadow and we will call that 'solar noon'." "Do we know how to find the average? Sure! That's easy. We learned that all we have to do is add up all our figures and divide the sum by the number of items we have."

One of the girls takes over: "What we really are doing is figuring out our longitude. We have a chart which shows all the time zones of the world. We are in the Central Time Zone so the time in Greenwich, England, on the Prime Meridian, is just six hours later than here. Now, noon for us comes at 12:16 P.M.

That means that the difference in time between noon here and Greenwich is 376 minutes (six hours and sixteen minutes). And noon occurs four minutes later for each degree that you move west from Greenwich. So if we divide 376 by four, we find that our longitude is 94° West." She also explains how they know that noon moves westward at the rate of four minutes to a degree. "Oh, that's easy. There are 360 degrees in a circle and also on the earth and there are 24 times 60 minutes, or 1440 minutes in a day. In one minute, the sun moves 360 divided by 1440, or ¼ of a degree. In four minutes, it travels one degree."

Where did the children get this information? They found some of it in their science textbook, some in the encyclopedia, and some in children's science books. The rest of it they got from Mr. Golden. "Gee, he's wonderful. He can explain things so well. He takes his time and he helps us understand. He shows us how to do the problems."

Mr. Golden describes the work of the group which is finding their latitude. "They are using simple homemade astrolabes. They 'shot' the Pole Star for the past few nights. According to their figures, our latitude is about 37° North. And that's not too bad either. They are not off by more than a degree. It is certain they know what latitude is, and they can explain it and can demonstrate how you can determine it. Of course, it will be important to see that the entire class comes to understand what this group now knows. But that will be done when they give their reports."

Three girls and a boy return from the library where they have been working on a report on the moon. Mr. Golden has them join the group which is studying light years. "You can finish your report later. Susan, see if you can explain what we found about the meaning of a light year. If you can explain it so that this group can understand it, I'll know that you will be able to

explain it to the whole class." Susan hesitates and then starts. "A light year is a distance. It is the distance that light travels in one year. Two great scientists, Michelson and Morley, found that light travels at a speed of 186,000 miles in one second." It is obvious that this information is just parroted. Mr. Golden stops her. "Just a minute, Sue. Say it in your own words. It will be much better that way."

After a few seconds of thought, Susan starts again. "Light moves very fast. It can go 186,000 miles in one second. That is the time it takes to say 'one thousand and one.' That means that light can go a lot further in a minute and very much further in a day or a year. But the stars are so far away that the light from them takes years to reach the earth. In fact, the nearest star, except for the sun, is a little more than four light years away." Mr. Golden is much more pleased with this. "Good, Sue. Now, Jerry, just how can we find the number of miles in a light year? Remember, you want to do this the way you are going to explain it to the entire class."

Jerry assumes the role of the teacher. "If light goes 186,000 miles in a second—and we know it does because Michelson and Morley did some experiments and showed that it did—then it must go 60 times as far in a minute. Now all you people get out your pencils and papers and figure out how far it goes in a minute." He waits while the others do the multiplication. "Who has the answer? Yes, Bill?" "I get eleven million, one hundred sixty thousand miles." Jerry asks him to put his work on the board and Bill goes through the problem. As they go on, Jerry gets from miles per minute to miles per hour and then to miles per day and finally to miles per year. Of course, the number grows to be tremendous. The final number is 5,865,696,000,000 miles per year.

Mr. Golden and the group begin to work on approximation of

answers. He shows the group that using round numbers for the multiplication problem can give an answer such as "6 million, million" which, for the purpose at hand, is quite satisfactory. The children learn about "estimation" and "approximation." This is another very important part of developing an understanding of quantitative ideas.

An analysis of the work that Mr. Golden has been doing is now in order. He has used many techniques to get the children more and more able to:

1. Frame the questions which they need to answer.
2. Find the answers to these questions.

First, of course, he set up the situations in which the quantitative aspects under consideration had to be solved in order to find satisfactory answers to the questions. It was he who helped the children develop the committees: one for finding longitude, one for finding latitude, one that studied about the moon, one that worked on stellar distances, one that studied the solar system. Then, he did not simply lecture to the children. Rather, he had the resources and the information which could be tapped by the groups so that they could carry on their work intelligently. In some cases, he had to provide some answers himself. It was he, for example, who needed to explain the meaning of a "light year." He was also a resource person. He had tried out the experiment on finding longitude so that he could help the children when they did it. He had made an astrolabe. He knew what encyclopedias and textbooks the children could use. In short, he had planned thoroughly.

These things he would do for any unit. In this unit, though, he had made special plans. He had deliberately chosen materials that involved quantitative ideas. Most science work (and some social science work) involves quantitative ideas. Whether quan-

tity is included in the unit depends on the teacher's plan. Mr. Golden wanted a study of quantity, so he planned for it. In searching out the materials for his unit, he had done three things:

1. He chose materials which had quantitative ideas as an integral part.

2. He chose material in which the mathematics was not too difficult. Neither the concepts nor the computational work was beyond the experience and ability level of the group.

3. He chose science material which was directly related to the personal needs and interests of the children. They wanted to solve these problems, and it was possible for them to do so.

It is important to note that there are many other areas of science commonly found in the curricula of our elementary schools that lend themselves to such quantitative work. The following are a few examples.

STUDYING THE AGE OF THE EARTH

In a study of the age of the earth, it is necessary that the children have some real and personal experiences to which they can relate so that numbers like 300,000,000 years ago for the Age of Trilobites, 65,000,000 years ago for the last of the dinosaurs, and 2,000 years ago for the beginning of the Christian Era can be distinguished one from the other. One way to do this is to make a "time-line" for the wall of the classroom. This involves an understanding of the mathematical concept of "proportion."

A frieze or time-line of the "History of the Earth" with the important events in this history pictured and placed in their approximate mathematical positions along the line can be made.

Thus, at the beginning (or "end," if you will) of the frieze, there can be a picture of "us." Then it can go back to "grandpa," and from there back to Lincoln or Washington. Then it can go back to the discovery of America and on back to the birth of Christ and further back to the Ice Age. The major mathematical problem will come as the children need to understand that if fifty years (the difference in age between "us" and "grandpa") is represented by one inch, then the picture of Washington must be about five inches back along the line, and the cross representing the beginning of the Christian Era must be 39 inches back from the picture of "us," and the glaciers must be even further back. Of course, this will take a lot of work. The children will need to be shown that if they want their whole line to be shorter, they will have to use a smaller scale. Thus, instead of making an inch represent fifty years, they could make an inch represent one hundred years or even five hundred years.

Furthermore, they will need help in understanding just how long "time" runs. The line can start on one wall and run around and around the room. A simple device for doing this is a string with important dates marked off at appropriate distances by pictures which the children have drawn. A line which has a scale of one inch to one hundred years would need to be 833 feet long to represent 1,000,000 years. That is too long. But a line which has a scale of 1,000 years to the inch needs to be only 83 feet long. These kinds of quantitative problems can and should be a part of science work.

GROWING LIVING MATERIALS

One of the important parts of raising living materials such as fish, plants, protozoa, and the like is preparing the correct media for them. Protozoa grow very well in a salt solution called

Ringer's Solution. Its formula is: 3 parts of distilled water to 1 part of "sea water." The stock sea water is made of:

8.0 grams of sodium chloride
0.2 grams of potassium chloride
0.2 grams of calcium chloride
0.2 grams of sodium bicarbonate
1000 cubic centimeters of distilled water

This solution can be purchased from a science supply house. But, if the teacher is interested in working on the development of quantitative concepts, it would be much sounder to purchase the ingredients and have the children weigh out the necessary amounts for the preparation of the stock solution.

UNDERSTANDING THE SIZE OF MICROSCOPIC ORGANISMS

While some microscopic organisms are hardly visible to the naked eye, there are others which are very readily available. Rotifers, for example, from ponds, streams, and ordinary aquaria can be seen as tiny dots swimming in a drop of water. If such dots are projected through a micro-projector onto a screen, the children can measure the image of the animal on the screen and compare this length with the actual length of the animal. As they note the complexity of the animal, as seen through the projector, they can consider this complexity in the light of its tiny size.

Of course, the children also can work out some of the meanings of tiny sizes if they study the microscope or the micro-projector itself. When a microscope is marked "400 power," it means that what is seen through the eyepiece is magnified 400 times. In other words, if an object is actually 1/400 of an inch long, it

appears to be an inch long under the microscope. This, too, is material which children can be helped to understand.

Summary

Mathematics is all around. It is an integral part of our lives. As the teacher chooses the material which he is going to help children learn, he must consider this important area. In planning science units, it would be well to keep these principles in mind:

1. Mathematics is an abstraction. Fundamentally, it is a series of concepts or generalizations. In order to develop clear and comprehensive generalizations, children must first understand the individual items from which these generalizations are derived. The teacher, therefore, must be certain to provide common experiences from which the students can derive these concepts.

2. Mathematics is rational. It can be explained and understood simply by finding the purpose and the logic of the given process. Numeration is for counting. Algebra is for expressing relationships. Geometry is for measuring.

3. Mathematics is a skill. It is the shorthand language of quantity. As such, it must be learned in the same way that children learn any other skill. They must understand it. They must practice using it. They must use it in their everyday lives.

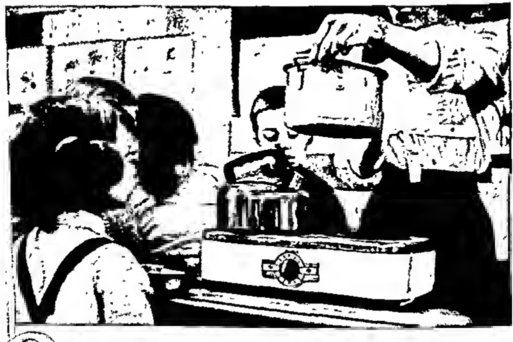
4. Mathematics is a tool. In and of itself, it has worth only as a game. But, used as an instrument for understanding the phenomena of the world around us, it becomes the wonderful and simple adjunct of these phenomena. As children understand their world more and more fully, they appreciate and enjoy it more.

A FIRST GRADE
LEARNS ABOUT RAIN

"This is my picture of rain."

"When we cool the water in the pot with ice cubes . . .

. . . water condenses on the outside of the pot."



VIII EXPERIMENTS AND EXPERIENCES

WHENEVER people think of science, they immediately think of experiments. The two ideas have become almost synonymous in the minds of most people. And this is rightly so because modern science is closely interwoven with experimental work. But often there are misconceptions about the scientist and his experimental work. Consider the stereotype of the scientist that has been built up. A scientist is a fellow who walks into his laboratory and wanders through a maze of complex, unusual, and exotic apparatus. Then, with mysterious "Sherlock Holmes" insight, as he looks at the apparatus, he suddenly comes forth with a long and happy "Aha!" From this amazing insight, he supposedly comes up with the answer to some problem which had baffled the minds of great men from time immemorial. This idea is even more confusing to most of us because in our minds experiments are often confused with exercises that we performed in our high school classes.

These exercises, called "experimeots," were almost inevitably repetitions of some application of a principle that had been studied either in class or in the text or in both. For at least the last sixty years every high school biology student has performed an "experiment" on osmosis. Some classes hollowed out a carrot, fastened a tube oo top of the carrot with wax and placed this apparatus in a molasses solution. Then they watched the molasses as it slowly rose up through the carrot and into the tube. Other classes used an egg and chipped off the bottom of the shell being careful oot to break the inner membrane. Next they punctured the other end of the egg and, using wax, fasteoed a loog tube over this opening. This heavily encumbered egg was then put into an appropriate solutioo and the studeots watched the solutioo work its way up the tube. Variations on this theme were oumerous. Sometimes a thistle tube covered with an artificial membrane served in place of the egg or carrot. Sometimes some other vegetable replaced the carrot. But this kind of an experieoce was as sure to take place in elemeotary biology as was the sun to rise in the morning. What was most disturbing was that everyooe knew what should happen before the "experiment" was performed and, if the "experiment" worked, the usual attitude_was "so what?" And if, as often happeoed, the "experimeot" fizzled, this was put down as the normal expectancy of high school science where "nothing ever works." After all, before doing this experiment, every student had read about osmosis in his textbook. Then the subject was discussed thoroughly in class. Finally, the "experiment" was set up in the laboratory.

This osmosis episode was, of course, no experiment at all. It was a demonstration of a principle carried out by the students. That it had values must never be denied. Some students could never understand the principles involved unless they had a chance to try them out for themselves. Others learned best through their own experiences and could not profit solely from

reading about osmosis or from seeing the teacher perform such a demonstration. And everyone could profit from working with simple science equipment. Truly, experiences which demonstrate science principles have a place in the classroom, but such demonstrations must not be confused with experiments.

The whole concept of experimentation and the experimental method has an interesting history and one that is worth review for elementary school teachers. Some four hundred years ago the scientific revolution began and it has not yet ended. This revolution was unique in that its base was a simple idea, a simple directive. Fundamentally, all that it propounded was: In order to understand a phenomenon, it is necessary to examine the phenomenon. Examine what is happening. Look at it with care. Measure all of its measurable aspects with precision. In order to understand, to really know, to find causes, to predict effects, the person must set up situations in which the phenomenon and the relationships among its various factors can be seen. This revolutionary approach is the most important contribution of modern science to world thinking. And this experimental approach to reasoning and to living is one of the essentials which must be learned by children as part of their elementary education.

Obviously what so often passed for experimentation in school classrooms is not that at all. It is incumbent upon us to find out what an experiment actually is and what the characteristics of the experimental method are. Really there is no such thing as "*the* experimental method." Nor is there "*the* scientific method." There are, in fact, as many scientific methods as there are scientists. Over and over there have been attempts to outline the steps in problem solving. The steps most often given are:

1. Delineate and state the problem
2. Look for pertinent data

3. Propose a working hypothesis
4. Test the hypothesis through experiments
5. Reach an appropriate conclusion

There is no doubt that these activities are all part of the work of the problem solver. But just teaching these steps to children will not guarantee that they will be scientists or, for that matter, that they will use these problem-solving techniques to work on their own problems.

EXPLORING AND EXAMINING THE ENVIRONMENT

What a scientist is and how a scientist works is quite closely related to what children are like naturally and how they act in many situations. Both scientists and children are explorers. Both aro avid examiners of their environment. Both try to manipulate and control the forces and the phenomena with which they are surrounded. This is all to the good for the elementary school teacher who can do much to foster the inherent exploratory characteristics of his children. There is, however, one important difference between children who explore and scientists who work in science. Children, as they try solving problems, as they explore their environments, are likely to work in a haphazard or trial-and-error way. They try something. If it works, good. If not, they try something else. They frequently do not reason from their past experiences and from the experiences of others. They do not search out clear statements of their problems and establish working hypotheses upon which they build their experimental and exploratory efforts. Scientists, on the other hand, use very rational techniques in their approaches to the problems with which they work. Their interests are directed and their work is quite specifically determined by these interests. As a capable scientist works on a problem, he

knows what he is doing, and, while he does not know what will result from his examinations and experiments, he is not on a wild fishing trip just looking for anything that might turn up. What the elementary teacher needs to do, then, is to keep the children *exploring their world while at the same time leading* them into an organized and planned study of their environment.

It is the rare individual who has a list of problems lined up which he wishes to solve. Furthermore, when such a person is found, if he is a student, he is likely to be thought of as a nuisance. His constant questioning is the source of much irritation to the people around him. The wise child soon learns that questioning is not generally acceptable behavior and most children soon stop thinking of questions to ask. Those wise ones who continue to think of questions, keep their questions to themselves and surreptitiously and furtively look for the answers by themselves. Questioning is hardly an encouraged activity. Yet, this is the nature of scientific work. And this kind of an approach to living, this approach which says in effect that there are no absolutes and that all that we do must be considered as based on our best judgments at that given time is the very approach which can lead to true problem solving and sound "scientific" living.

SCIENCE TECHNIQUES FOR SOLVING PROBLEMS

Essentially, then, the experimental methods that should be fostered in children are the methods of continuous questing, continuous searching, continuous examining of what is around them. In order to carry out this process of searching in a more organized and a more economical way, there are some techniques which can be taught to children. Take, for example, the matter of propounding hypotheses for the solution of a problem. This is what each of us does as he goes about solving even

the simplest personal difficulty. If your pen stops writing, the first thing that you do is to give it a shake. What are you saying through this action? Put into words it might be: "Perhaps something is clogging the pen. If I shake it maybe I can get the ink to flow again." After you shake the pen, you try to write once more. If you can, if the ink flows, good. If not, what then? Perhaps you try scratching the pen on some scrap paper, or perhaps you try cleaning off the point with a tissue. Finally, if none of these actions help, you get ink and try filling the pen. Maybe this works and maybe it doesn't. In any event, you have made a series of guesses about why the pen stopped writing and have tested each of the guesses in turn to try to correct the fault. But these have not been just wild and random guesses. When the pen stopped writing you did not try painting it a different color to see if that would help. Nor did you try invoking some magic spirit to help set the ink flowing. No, your conjectures were reasoned; they were based on your previous experiences with pens and why they write and why they stop writing. And your hypotheses, for that is what those guesses were, were based on rational experiences which you had had with other pens at other times. The techniques for propounding and using hypotheses and for carrying out the other steps which lead to rational thinking and experimenting can be taught through the use of science.

This is the way things stand. First, there is a need for developing children's inherent capacities as explorers and as questioners. As children develop this ability to question and to examine critically, they become more mature and more creative people. And as they become more creative, they make the kinds of contributions that are wanted in a democratic society. Second, this creative and questing approach to the world is not implemented by a single technique or set of techniques. Yet, there are certain principles which have value for the creative problem solver. For one thing, people who want to solve problems through the use

of these principles usually state their problems succinctly and clearly. Then too, they propound and try out a series of hypotheses for solving the problem. They test the hypotheses over and over again and look for all sorts of ways to prove or, equally important, to disprove their conjectures. They devise all kinds of ways for doing their experiments and develop new machines and new techniques for their work, always looking for appropriate tools and for ingenious ways of applying old ideas to new situations.

In order to build an elementary science program that will foster this kind of science activity in children, the teacher must recognize that he will be doing many things besides experiments. Involved in the science program will be reading and reference work, demonstrations of principles through a variety of experiences, films, or field trips. The actual work with materials in an experiment, however, should be considered to be of prime importance. Children who have a chance to work with materials and to try out ideas with those materials, particularly as they are guided into organized and rational and planned thinking, are much more likely to retain what they have learned from their experiences. An example of how this kind of work was carried out with a fourth grade follows.

A FOURTH GRADE EXPERIMENTS WITH SEEDS

Mrs. Hamilton planned a unit on seeds and how they germinate. She collected a variety of seeds and had the children bring in some too. There were all different kinds: peas, beans, apple seeds, orange seeds, nuts, and a number of others. Mrs. Hamilton opened her introductory lesson with a question. "What do you think we need in order to start these seeds growing?" Very soon she had the following list of "necessary" factors:

soil
water
sunshine
food
heat

Obviously, some of the things mentioned were not necessary for the germination of the seeds. And some of the factors that were necessary were missing from the list. But Mrs. Hamilton used this list as a starting point for work on the germination of seeds and also used it as the base material for teaching the class to use experiments. And true experiments these were. Of course, the experiments were in areas which had already been explored by others. None the less, for these fourth graders who did not have the answers to the questions the teacher had put to them, this was real experimentation.

Mrs. Hamilton went on. "We ought to think about this list. Do you suppose that all of the things that you have listed are necessary? And do you suppose that we have left anything off our list? We ought to do some experiments, some real scientific experiments, to see if all these things are necessary. Take 'soil' for example. How could we find out if soil is necessary for seeds to start to grow?" The actual work of setting up the experiments now began. First came the statement of the problem. After a considerable struggle with words, the children came out with this statement:

"Is soil necessary for seeds to begin to grow?"

The question was discussed at some length and Mrs. Hamilton stressed the word "begin." She wanted to make clear to the children the fact that they were working on factors needed to start seeds growing rather than on factors which aided growth of plants. She realized the importance of a careful use of words and stressed this language skill in her work.

The hypothesis which was implicit in the statement of the problem was that soil was necessary for the germination of the seeds. It was important that the children see that a hypothesis is a reasoned guess which is made in order to proceed with the solution of the problem. A hypothesis is not necessarily true. In fact, this one was false. Mrs. Hamilton knew that it was false, but she said nothing about this to the children. Instead, she went on. "Bob, you were the one who said that soil was necessary. Are you certain that it is necessary? Tell us why you think it is." Bob was a bit flustered at the question; he had not thought about germinating seeds before, and he answered hesitantly, "Well, you always plant seeds in soil. I know that we planted our garden in the soil. And all our corn, and peas, and stuff grew fine. So I think you need soil." Mrs. Hamilton turned to Jerry who had been waving his hand excitedly. "Yes, Jerry?" "I don't think you need any soil. I know that we had some bean seeds in a bag under the sink and when I took them out because I was going to bring them to school, they had some little leaves on them. My mother said that they had started to grow in the closet." This was just what Mrs. Hamilton wanted. In fact, if Jerry had not brought up the matter of possible contradictory evidence, she had planned to do it herself. "Well, now this calls for a real experiment. Bob has said that he thinks soil is necessary. In fact, he says that for their garden at home, his father always plants the seeds in soil. But Jerry says that some of the seeds that he had at home started to grow without soil in the paper bag where they were kept."

Fourth graders, who are usually nine and ten years old, are not likely to be able to deal with the generalized concepts of hypothesizing and the control and reliability of experiments. However, even though the children did not realize it, they had already presented several hypotheses and Mrs. Hamilton had the children state their hypotheses and plan controlled experiments with sufficient samples so that they could be reasonably reliable. The

abstract concepts of "hypothesis," "controlled experiment," and "reliable experiment" she left for work at later grade levels. Here is how Mrs. Hamilton went on.

"Well, Bob, you think that you know one of the things that is needed in order for seeds to begin to grow. Could you tell us what you think it is?" Bob stuck to his point, "I guess that you need earth to make the seeds start to grow." Mrs. Hamilton went on. "Fine. Now we need to set up an experiment which will show either that Bob is correct or that he is wrong, because we really want to know whether or not soil is needed. Do you supposo we could figure out such an experiment?" Soon the ideas came thick and fast. "We could plant a seed in some earth and water it and seo if it would grow." "Sure, but that wouldn't prove that you needed earth. Even if it did grow, it wouldn't show that you needed the soil." "Why not? If it started to grow, wouldn't that show that you needed soil?" "Nah, that would only show that it *could* grow in soil. But it wouldn't show if the seed could grow when there was no soil." "Say, that's right. I guess we would have to have one seed in soil and another out of soil. Then we could see which one would begin to grow. That would be right, wouldn't it, Mrs. Hamilton?"

"Hold on a minute. You are getting so many ideas here that we need to sort them out. Certainly we need to have at least one seed in soil and at least one other seed out of soil. But what about the way in which we take care of the two seeds?" In a few minutes the children recognized that each of the seeds must be treated identically except for the matter being investigated. In this case, the factor being investigated was the need for soil. Mrs. Hamilton stressed this point and discussed the factors that needed to be identical. The children decided that both seeds should have water, warmth, sunshine, and that both should be given some plant fertilizer. Mrs. Hamilton did not say anything to the children about the unnecessary factors (sun-

shine and fertilizer) because they were going to consider those factors later. Certainly, she was not going to tell them they were wrong in including them. However, she did have a number of children take on the responsibility for finding reference materials on seeds and how they germinate.

On the other hand, Mrs. Hamilton did find it necessary to introduce the concept of reliability to the children. "There is a chance that something can go wrong with this experiment and we can avoid it very easily. Does anyone have an idea about what could go wrong?" The children were baffled at first, but then started to suggest all kinds of possibilities. One said that the water might dry up. Another thought that it might get too hot or too cold. Finally, one suggested that the two seeds that they were going to use might be "no good." After considering these possibilities for a time, the class decided first to use newly purchased seeds, and second to have enough seeds "planted" so that they could be sure to get results. Even though they were not aware of it, they were setting up their experiment so that they could get reliable data from which to draw their conclusions. This, of course, was what Mrs. Hamilton wanted. In addition to satisfying the requirement for a sounder investigation, planting a hundred seeds meant that each child in the group could be an active participant in the experiment rather than simply a passive observer. It was more likely that each child would learn if he actively worked with the materials.

Knowing that many of these children would lack the patience to carry on this project for a long period of time, Mrs. Hamilton chose quick sprouting lentil beans. The seeds were planted in a mixture of soil which was gathered from the school yard and the control seeds were placed on paper towels which were kept moist by crumpling them and placing them in dishes of water. The children watched the seeds from day to day. They watered the seeds and fed them a solution of a simple, chemical fertilizer

which one of them had bought in a ten-cent store. It was three mornings later when the first two lentils showed the tiniest sprouts. The first sprouts were from the lentils on the paper, because the ones that had been planted had not yet had time to break through the soil.

With some difficulty, Mrs. Hamilton was able to make the children wait for one more day before they drew their conclusions. "Just think, maybe those two seeds sprouted by accident. Why don't we give everything another day and see what happens tomorrow?" The fourth morning found about half the open seeds sprouted and a few of the potted seeds pipping through the soil. With this situation, Mrs. Hamilton was ready to proceed to the next step. "Well," gloated one of the boys, "I guess that showed him you don't need dirt." Bob was all ready for an argument. But Mrs. Hamilton stepped in rather quickly and pointed out that this was not a matter of winning or losing. Rather, the class was trying to find out the factors necessary for germinating seeds. "Now what can we say as a conclusion for this experiment?" The children decided that what they had shown was that soil, while not a hindrance to the germination of the seeds, was actually not a necessary factor in their germination.

But Bob and several of the others were not satisfied. This, of course, made the experiment even more of an educational success and was exactly what Mrs. Hamilton had hoped would happen. Bob put it this way, "If you don't need soil to grow seeds, then why do farmers plant seeds in the earth? Why not just spread them out on a big concrete floor and let the plants grow on that?" Thus, the successful completion of one experiment led to other more complex and more advanced experiments. By the end of six weeks, that fourth grade class had carried on more than a dozen controlled and reliable experiments on seeds and plants. After another total group experiment on the need

for sunshine for germination, the class worked in groups and carried out *different experiments according to their interests* and abilities. Some worked on the need for nutrients, others on the possibilities of growing plants in water, still others on the use of different kinds of soils. The distinction between starting seeds growing (germination) and raising plants after they had germinated was made very clear. All of the children were actively involved in setting up the experiments and all worked on the project. Mrs. Hamilton set aside time each morning for the care of the experimental plants and reports were given during science periods. The class garden became a center of interest for the entire school.

Checking on the concepts that the children had learned, Mrs. Hamilton was able to see that they really knew the following things:

Seeds need to be viable in order to germinate. (The children learned to use the words "viable" and "germinate.")

Seeds need to be warm in order to germinate. (The children could not find the exact temperature but they did find that it needed to be above freezing and below boiling.)

Seeds need to be kept moist in order to germinate. (Some children tried growing seeds directly in water and also tried to germinate dried seeds.)

Seeds can germinate in the dark but plants need sunshine in order to grow.

There were several other concepts which the children developed *and they had a fine factual background on plants and their* growth. But the children had acquired much more than just information about seeds and plants. They had started to examine their world in a rational and experimental way rather than either through authoritarian or hearsay information or through waste-

ful trial and error activities. These experiments were an early experience for the children in rational, experimental, and creative thinking.

THE EXPERIMENTAL PROCESS IN THE PRIMARY GRADES

This sort of work need not wait to start at fourth grade level. Even first graders can be introduced to very simple experiments and the experimental process. After all, the children already have used trial and error in many situations even before they came to school. They have built block buildings without careful balance and have seen them topple. They have "experimented" with paints and crayons and with other materials in their environments. Given an opportunity to try things out in an organized fashion, they can begin to understand that an experiment compares the possibilities which exist in a given situation. Of course, the situation must be kept simple. It is probably better to work with plants rather than with seeds and to keep the experiments on a very elementary level. For example, first graders could very well experiment with the need for watering plants. They could grow some small plants and could water one set and leave the other set without water. They could then find the results and reach some tentative conclusions. The teachers of the subsequent grades can develop the experimental work by building on these simple experiences with rational thinking and experimentation.

While experiments and experiences at the primary level must be much simpler and much more elementary than in the upper grades, nevertheless, from his earliest days in school, the child needs opportunities to see things happen, to try things out. From their experiences, they must be able to say: "When I do this, then this will happen." These experiences with simple cause and

effect relationships are important building stones upon which later, more complex experimental work can be done. Here is the work that Miss Hicks did with her second grade class in a study of prisms and their effect on light.

A SECOND GRADE STUDIES PRISMS AND LIGHT

On several days, as Miss Hicks watched the children during their rest period, she had noticed their interest in the spectrum that was formed by sunlight streaming through the aquarium. The children were fascinated by the dancing colors and many of them noticed the patterns and called them to the attention of both the class and the teacher. "Look, oh look, there they are again. Miss Hicks, where do those colors come from?" As the questions continued, Miss Hicks decided to build a short unit on the topic of color.

The first lesson was a simple one. Immediately after rest time, and while the children were still talking about the colors that they had seen, Miss Hicks brought them together for a discussion. "Those colors that we saw on the wall, do you know what they are called? Yes, they are called a rainbow. How many of you have ever seen a rainbow? Gina, tell us about the one you saw."

Gina chattered away about the summer storm and how her Daddy showed them the rainbow in the sky after the storm was over. Then several other children recalled—or thought they recalled—similar incidents. "Did any of you ever see a rainbow at any other time? Did you ever see a rainbow when it wasn't raining?" Three experiences were related. First, some children had noticed a rainbow effect in a spray of water from a garden hose. Then, a child who had spent the past summer at the beach told of seeing rainbow colors in the spray from the waves

as they hit the rocky shore. Finally, one child told of seeing the rainbow colors in the spray of a waterfall that he had visited with his parents.

"Now all of these rainbows were made by sunlight. But there was one other thing that was there in each case where people saw rainbows. Does anyone know what it was?" In a few minutes, Miss Hicks had the children understanding that the other factor was water. "Here in the room we have the aquarium. And Gina's rainbow came after the shower. And then there was the rainbow from the spray of the hose—that's water, you know. And then there was the one at Courtney Falls—and that is water. And then there was the rainbow in the spray of water which Jerry saw at the beach. I brought in some glasses and some bowls so that we could try to make some rainbows."

A very simple experience followed. The children tried different shaped glasses and different amounts of water and found that when sunlight was allowed to pass through a glass container of water, a rainbow was formed. The same light passing through an empty glass gave no such rainbow. A simple experience chart was prepared. This is what it said:

We made a rainbow.
We put water in a glass.
The sun shone through the glass of water.
The rainbow came out on the floor.
We could make the rainbow shine on our clothes.
But we could not carry it away with us.

As the lesson ended, Miss Hicks promised them further work with rainbows. "Tomorrow I am going to bring in something else that we can use to make rainbows. Then maybe we can find out some other things about them." The lesson was very simple. At no point did Miss Hicks talk about their work as an experiment. Yet, in a very real sense, the children were doing an ex-

periment in the classic scientific meaning of the term. The problem was to find a common factor present in all of the experiences which the children had had with rainbows. The hypothesis was that the factor was water. The children tried some containers with water and others without it. As a conclusion, the children found out that sometimes when sunlight shines through a glass container of water it forms a "rainbow" or spectrum.

During the second lesson, Miss Hicks introduced the children to the effect of a prism on light. It was an excited group of children who watched the colors as they moved on the wall. They tried all manners of movement and all kinds of random play. After giving the children enough time to try out the prisms, Miss Hicks called the group together to summarize and form some generalizations. "Well, who has found out something special about his prism that he can tell us?" Soon odd bits of information were contributed. "If you turn the prism, then the rainbow moves on the wall." "If you hold the prism sideways, the rainbow is sometimes on the floor and sometimes on the ceiling." "Once, I think I saw two rainbows at the same time. One on the floor and the other on the ceiling." Each of these statements was examined and studied. The child who proposed the idea was required to demonstrate his statement with the use of one of the prisms. Mostly, however, the lesson was an exploration of the phenomena observed when a triangular glass prism intercepts sunlight. Trying out the prisms was the most important part of the lesson, but the children also received practice first in making careful observations and then in describing with accuracy what they had seen.

The third lesson, which was directed observation, required a more formal organization both on the part of the children and in the setting which Miss Hicks prepared. During this lesson she wished to have the children note the order in which the colors of the rainbow appeared and the constancy of this order.

"Today we are going to work with the prisms again. But, before we start, there are two questions that I want to ask. First, do you know the colors that the rainbow has in it? Second, does the way the colors show ever change?" As the children worked, Miss Hicks made sure that they followed through on observations to find the answers to the questions which were the basis of the lesson. This kind of planned, careful observation is an important part of the experimental method and all primary teachers should include it in their science programs. Miss Hicks was particularly anxious to have each child do his own observing and each child had an opportunity to tell about what he saw. The observations which the children made were summarized by the class as follows:

> The colors of the rainbows that we made with our prisms were:
> Red, Orange, Yellow, Green, Blue, Violet.
>
> The same colors were always next to each other. The order of the colors was: Red, Orange, Yellow, Green, Blue, and Violet.

Later lessons had the children working with colored cellophane sheets of the primary colors to find out what happens when prisms are used with colored light. While Miss Hicks was not stressing the experimental method, all of her plans and all of the program was directed towards having the children engage in experimental activities which later could be used by the children to develop experimental approaches toward the phenomena around them.

EXPERIMENTS FOR A SIXTH GRADE

There are many kinds of experiments for sixth graders to perform and it is important that they have a wide variety of such

experiences. For children at the sixth grade level, the work with seeds and plants could be much more complex and the experiments and the experimental method used should be much more exact. Children of eleven and twelve can grasp the concepts of hypothesis and of control and reliability of experimental work. Teachers at that level, as they plan their science units, should include materials on the nature of experimentation. For example, if the unit on seeds were done with a sixth grade rather than with a fourth, the following additional material might have been included in the first part of the lesson, after Bob and Jerry had discussed the need for soil in germinating seeds.

"There is a word that we need to use now. It is the word *hypothesis.*" The teacher writes the word on the board. She could have the children look it up in their dictionaries and then spend some time on its meaning and importance. Or she might simply say, "I'll tell you what it means. A hypothesis is a kind of guess about the answer to an experiment. But it is not just an ordinary guess. It is a guess that you make because you have some ideas about what the answer might be. It is a guess that you have thought out, and not just any old thing that comes into your mind. For example, if it's your birthday and you find when you get home from school that there is a surprise package for you, you might make a wild guess and say that the package comes from the King of Sweden. But if you make a carefully thought-out guess, what would you be likely to say?" The children mention relatives such as parents, or brothers and sisters, or aunts and uncles. "Yes, a present on your birthday would most likely come from one of your relatives. So a hypothesis about who gave you the present would be that it was given to you by one of your relatives."

Carrying on from there, the teacher of a sixth grade could have the children state hypotheses and build experiments on these working hypotheses. In the same way, the sixth grade teacher

would want to plan for time to discuss both the question of control in experimentation and the question of reliability of an experiment. It is not likely that the teacher would spend much time on the question of validity. That concept is probably too difficult for most children in the elementary grades and is more appropriate for senior high school science. On the other hand, just as Mrs. Hamilton worked to have the fourth grade experiments both controlled and reliable without going into a study of these concepts, a sixth grade teacher would try to have the children devise experiments which would prove or disprove what was being studied; in other words, experiments which would be as valid as circumstances would permit.

In addition to the work that sixth graders can do on the experimental process, they can perform many more experiments than the fourth grade. For example, they could make studies of the development of seeds and of plants in differing kinds of soils—clay, loam, sand; they could do some simple work with hydroponics which would involve a study of some chemicals and very elementary chemistry. The experiments at the sixth grade level should be much more quantitative in character. The children can and should *measure and weigh the materials that they* use and should keep accurate quantitative records of their results where such records are important for their studies. Furthermore, at the sixth grade level, since there is such a wide variety of ability, the experiments should be carried on by groups of children or even by single children where necessary so that each child works on those problems which are appropriate to his own level of ability and of interest. Here is a short list of areas from which experiments might be derived:

1. *In a study of seeds and plants,* experiment on: effects of different soils; effects of different commercial fertilizers; germination period of different kinds of seeds; rate of growth of plants under diverse conditions.

2. *In a study of conservation,* experiment on: effect of alkalinity and acidity of soil on various plants; effects of chemicals (acids in particular) on various rocks; effect of running water on soils.

3. *In a study of combustion,* experiment on: effect of oxygen on burning; effect of carbon dioxide on burning; effect of air on burning.

4. *In a study of water and its properties,* experiment on: buoyancy of waters with differing amounts of salts in them; freezing point and boiling point of various salt solutions; volume of water as compared to the temperature of the water.

5. *In a study of air and its properties,* experiment on: effect of temperature on the ability of air to hold water; compressibility of air; relationship between temperature and volume of air; relationship between the pressure and the volume of air.

6. *In a study of the body and how it works,* experiment on: various diets and their effects on growth; amounts of water in various foods.

These various experiments would, of course, be parts of general units. For example, the experiments with water and air would fit into a study of weather and its importance in man's life. The experiments must be so presented that they are not separate from the class program but rather a unified part of the whole.

In addition to the experiments, there need to be various experiences which explain for the children the general principles of the science which they are studying, and which give them a chance to observe both quantitatively and qualitatively the various phenomena around them. But demonstrations must not be confused with experiments. Each has its own place and each is important. The demonstrations do two things: first, they give concrete and visual illustrations of science principles in action; second, they give the participants a chance to be actively en-

gaged in the use of some tools of science (science apparatus) and to do some of the measuring that is so important for modern science work. The experiments also do these two things, but they do a third important thing. An experiment should give the children a chance to learn something of the "if-then" relationships of the universe and should stress the importance of searching out answers through the experimental method.

Summary

Early in the book it was pointed out that the schools had responsibility for helping children acquire that information and develop those attitudes about scientific phenomena which would allow them to be participating citizens in this technical, industrial, democratic society. Closely tied to the concept which backs this thesis is the entire philosophy upon which the experimental approach to the world is based. In the first place, the experimental approach implies that men have not only the right but also the responsibility to examine all of the questions with which they are concerned. Secondly, this approach suggests patterns of behavior and techniques for study and work which readily lend themselves to a thrifty and useful consideration of man's problems.

Looked at from the child-development point of view, the experimental approach has still another function. Learning is an active process and the more it involves the various senses, the more likely it is that the material being studied will be learned. So much of the school curriculum is in the realm of the abstract and does not lend itself to active learning situations that it is extremely important to exploit every possible learning area which can be made concrete. Elementary school science is such an area. Almost all of the science generalizations which are taught in the elementary schools can be explained through concrete, personal experiences. Each individual child can have many opportunities to learn by trying things himself.

It is necessary, however, that children develop an understanding of and facility with the techniques of the experimental methods. But children come to school equipped with the prime factor which is necessary for developing these skills. They come with the innate curiosity and with the natural desire to explore which is the essential ingredient of the scientist. The task of the teacher is to lead these children from their random explorations, from their use of a trial and error approach, to a rational and organized and experimental approach. In the course of doing this, the teacher must accomplish several important purposes:

1. The teacher must encourage the children's curiosity about the world around them. They must be encouraged to question, to examine, to wonder, to quest for explanations of what they see, and hear, and feel, and sense.

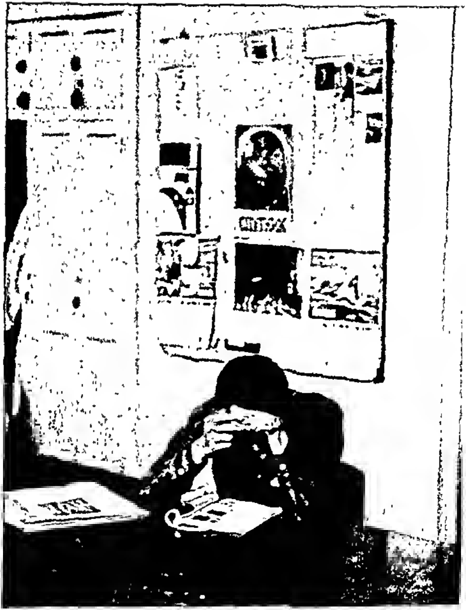
2. The teacher must foster accurate and precise observation of phenomena. When things are measurable, then children should learn how to measure them. When they must be described qualitatively, then children should learn to give as accurate descriptions as they are capable of making.

3. The teacher must sponsor the children in their search for unique and ingenious ways of solving problems and doing experiments. There is no single way in which a scientist works and the teacher must encourage each child to find new ways to solve old problems through the use of a variety of tools.

4. The teacher must watch after the children's safety and must work with them to develop the judgments necessary for safe living in such a technical society. Just laying down rules is hardly enough. True, there must be rules for safe behavior which are established by both the teacher and the children. But there must also be a rational and controlled atmosphere in the classroom which carries over into all phases of work and which keeps experiments in safe bounds.

5. The teacher himself must assume an experimental attitude toward his work and thus set a tone for the entire class.

Finally, it is well to remember that we learn by doing *and by reflecting upon what we have done.* A program in elementary school science must have within it opportunities for "doing," but it also must have opportunities for organizing the "doing" and for reflecting and examining what "has been done."



There is so much science happening every day.

Looking backwards, 150,000,000 years is not too difficult to comprehend.

IX RESOURCE PEOPLE, TRIPS, AND AUDIO-VISUAL AIDS

TWENTY-FIVE years ago, if a field trip was planned or if a film was to be shown in class, the prospects of such activities were enough to keep any elementary school class excited for a week in advance of the event. And the afterglow of such events, regardless of their intrinsic and inherent merits, was enough to cause a stir in class for weeks. But times have changed. Films and filmstrips are in everyday use in the elementary school classrooms. And field trips, while not as widely used as films, are, none the less, reasonably common. Children have come to accept such activities as a regular part of their learning experiences and to demand, justifiably, that such activities meet the standards of fine teaching to which they have a right. No longer will just any film excite them. The film must not only be appropriate to what is being studied, it must also meet artistic and cultural standards as well. Not every field trip is welcomed with unreserved joy. A field trip must now have a reason for being, and a reason that the children can understand and accept as

worthwhile, or it is looked upon as an intrusion in a regular and accepted routine.

In a modern elementary school, there is a need for a variety of experiences. Field trips, films, and television, the most vivid of such experiences, are often the framework around which children recall whole bodies of learning and entire sets of important generalizations. What makes these activities so important is that they allow children to enter into many direct experiences in areas where they have had no previous personal relationships. The chance to see and to hear living, dynamic events and the opportunity to witness phenomena which are far outside the range of their normal ken mean that the trips and audio-visual materials can bring children much of the very kind of education which they need. Through the use of a film, whole new backgrounds of information can come to a class. A field trip can widen and deepen a whole area of study for a group. A related and appropriate television viewing can make an esoteric and abstract topic become concrete, understandable, and personal.

Children, as has been noted, come to school with a readiness to learn. A group of first graders welcomes new educational experiences with relish. And fifth grade children go out to explore new ideas and new worlds with all the temerity of the boldest adventurers. Here, then, is the stuff from which sound educational practices can be made. For one thing, audio-visual activities can be used to develop entirely new areas of interest for children. These days few children have a chance or the patience and ability to witness personally the activities of animal families. Yet such activities always capture the imagination of children. Many is the group of first graders, many the individual six-year-old who has found a new range of interest in nature through a film such as "Beaver Dam." The film is just a record of the activities of beavers as they build their homes, work, play, eat, and care for their young in and around a dam site.

Nothing fancy, nothing spectacular; just a family of beavers at work and play. Yet the children sit enthralled because through such an experience they are able to find new interests which will add to their maturity. This is not to say that all children must learn about beavers in order to become effective adults. Rather, each new area of exploration, each new interest that children develop allows them to broaden the range of knowledge which all must have to function effectively in today's world.

A FIFTH GRADE TRIP TO AN AIRFIELD

Beyond the task of developing new interests, field trips can extend the range of interests which have already been aroused. Mr. Watkins had a rather typical fifth grade. His boys were concerned with the usual sports, and scouts, and game programs; his girls were busy being Brownies, and studying ballet, and adoring horses. But one interest which they had developed was somewhat unique to their area. The school was close to an Air Force base and planes of all kinds flew over the school building all day, every day. Of course, the children knew about many of the planes. Who could fail to know when a jet roared over school and the noise of its engines drowned out all conversation? And three of the pupils in the class were children of Air Force personnel. They became the authorities, though Mr. Watkins had to make sure that their information was correct. Most of the children had become quite interested in the planes and could identify many of the craft that used the field and could discuss the uses and merits of the various types of planes.

However, many of the children had never been close to a plane, and only one of them, one of the Air Force children, had ever been inside a plane. This child had flown from overseas where his father had had his previous assignment. With all of the

interest that was evident, Mr. Watkins felt that he should exploit it for educational reasons. True, he wanted the children to see close up some of the planes that they had seen previously only at a distance. And he wanted them to have the new experiences that would come from having a chance to get into a plane as it stood on the ground. But extending and expanding interests was also an important part of Mr. Watkins' objective. So, when he arranged for a trip to the base, part of the plans called for spending a considerable amount of time at the weather station and in the weather-briefing room. Mr. Watkins wanted the children to learn the role of weather forecasting and some of the important concepts of meteorology and their relationship to flying. For many of the children, even the idea that there might be a relationship between the two phenomena, flying and weather, was a whole new concept. But most of the children know to a greater or lesser extent about the weather station at the base.

The trip, then, was planned with just two major objectives. First, the children were to see some of the planes and were even to have a chance to go aboard an old transport that was in one of the shops. They would see the cockpit of the transport, have a chance to sit in the pilot's seat, be able to sit in the passengers' seats, fasten the safety belts, and even listen over the headphones on the intercom system. One of the pilots at the base was to tell them something about flying the transport and was to show them through the plane and around the hangar to see other planes.

The second objective was to extend the interests and information of the children beyond the planes themselves to the various areas of knowledge which made flying possible and safe. For this, Mr. Watkins proposed to take the children to the weather station and the weather-briefing room. In working out the plans with his contact at the base, he had to find a weatherman who

could explain the operations to the children at a very elementary level, someone who could answer the children's questions without giving them too much technical information which they could not digest. As Mr. Watkins planned the trip with the weatherman guide, he posed four simple questions which he suggested might be answered during the visit:

1. Why do airplane pilots need weather information?
2. What kind of information do the pilots need?
3. How do the weathermen gather this information for the pilots?
4. How do the pilots get the information from the weathermen?

Details aud special information about the weather services were to be avoided and technical questions were to be shunted to late in tho program when the few children who might want to ask such questions could have a chanco to be alone with the weatherman.

That, except for the thrill of lunch in the base cafeteria, was the plan for the trip. Ed's father arranged for the class to visit the field even though Mr. Watkins could have done it himself with just a telephone call to the information officer of the base. Parents are often very enthusiastic about showing children their places of work and sometimes need to be helped to see that children learn best when they do not have too much to learn at a time. It was with some difficulty that Mr. Watkins kept Ed's father from showing the children the Link trainer room, the aviation safety center, the fire station, and several other important parts of the installation. The trip was planned with two objectives. More than that would have been confusing to the children, and for many of them would have been a waste of time.

USING FILMS AND FIELD TRIPS TO ORGANIZE PREVIOUS LEARNING

Audio-visual materials and field trips have another function besides providing new interests and extending and expanding old ones. Films and trips, for example, can be used to establish functional relationships among a variety of previous learnings. Mrs. DeWitt's sixth grade class used a field trip to a power station to find out the over-all picture of the production, distribution, and uses of electric power in their community. The children had had many experiences with electricity. They knew its uses in the home. They knew about its uses in business and industry. They had several experiences with different ways of generating electricity. They had read about power stations and had even set up a model of a generating station with a toy steam engine that Mrs. DeWitt had brought to class. But to conceive of a coal pile big enough to operate a steam plant for sixty days or to visualize a boiler five-stories high was too much even for their vivid imaginations. For her children, Mrs. DeWitt wanted the trip to be an integrating experience. The purpose was to have the children develop a connected and unified understanding of the whole story of electric power, its production and uses. The children were to understand the flow of the process from a coal mine in Pennsylvania to the electric toaster on their breakfast table.

Mr. Zucker's class had the same kind of experience with a film. In their study of food and other natural resources, the children had learned many things. Each of these things was, in itself, a whole and important generalization. They had studied about foods and their relationship to health. They had studied about mineral resources and power resources and how they are used. But the whole big picture, the interrelationship of all of these smaller units, was not clear to the children. How did food relate to power? How did sunshine relate to atomic fuel? How did the

sea and its resources relate to healthy children? These were all beyond the scope of any of the units that had been carried out. The film that Mr. Zucker used was one produced by the Bell Telephone Company, "Our Mr. Sun." Originally, the program had been produced on television, but it was now available through the public relations office of the Telephone Company. What the film did was to tell the story of the sun and its importance to the earth and to man throughout history. Not only did it show how all of the natural resources of the earth were dependent upon the sun and why this dependency existed, but it also showed what might be expected for the earth and for men through the further scientific use of the sun's resources. Through this film, the children were able to pull all that they had learned together into a bigger whole, and from this new learning they could go on to work with wider and more complex concepts.

USING VISUAL EXPERIENCES TO VERIFY PREVIOUS LEARNING

A further value of these experiences can be found as they are used to verify what children have learned in the classroom. It is all very well to tell children that all of the trains between Chicago and St. Louis are controlled from a single control room, and that there are men in that control room who can start, or stop, or switch a train from one track to another simply by touching a button. But one has to see that sort of room really to believe that it is possible. And to get a true picture of a steel mill and its size one must either visit it or see a film which shows some of its vast operations. After all, reading about a cauldron of a hundred tons of molten steel means little in comparison to seeing the cauldron or to seeing a motion picture of it as it moves across the vast mill room and then spills its contents into molds as a man touches a lever in a cab

some hundred yards away from the moving crane and cauldron. Or take the matter of understanding a volcano in eruption—what it looks like, what it does. There are few American children who have seen such a sight, and even if they have, it is unlikely that they saw it under the calm circumstances necessary for a study of such a phenomenon. A film can verify all that they read about such a natural but awesome event and make such a scene meaningful beyond all the reading and listening that they could ever do. A good picture may be worth a thousand words, but a good film is worth a million. And a well-planned field trip with clear and defined purposes is even better than a film.

Another kind of verifying can be done with field trips and with films too. Principles which seem so extraordinary and unusual in a classroom often come to have meaning to children only as they see these principles applied in living and working situations. A small electromagnet made from a nail and a strand of bell wire and operated by means of a dry cell will pick up and hold a few paper clips so long as the current flows through the wire. Once the current is shut off, the clips fall from the magnet. Teacher says: "Now that is the kind of machine which is used to move tons of iron from one place to another." The reaction of the children ranges from skepticism and disbelief to one of amazement. Sure, a magnet can hold a few paper clips. But what kind of nonsense is being given us? How can a magnet pick up more than ten tons of iron at a time? That is much more than a big truck weighs. How could a magnet hold a weight like that? Then, as the children visit a site where such a huge electromagnet is at work and see the magnet lifting not ten tons but as much as fifty or sixty tons, as they see a magnetic crane lift a railroad car and move it from one place to another, they come to understand and verify the science principles which they have studied in the classroom.

The same kind of thing can happen with a study of such a topic

as radar. The children learn about some of the principles of radar. They learn how the radio signals are sent out from the station and how these signals scan the horizon for objects in the vicinity. They learn that such radio signals can go far beyond the range of the human eye and even far beyond the range of binoculars and field glasses. Furthermore, they learn that radar signals can penetrate fog, and rain, and snow. Then they learn how such signals bounce off the various objects in the radar range and are returned to the station and picked up on receivers at the station and identified. It is really quite incredible. As the children shift in their beliefs from doubt to acceptance, the danger of such acceptance without benefit of confirming and verifying experiences is that they will think of such wonderful instruments as "magic." But a trip to an airport to watch the operation of the radar installation and to verify in their own minds its operation and use, both can help the children understand the machine and its uses and can dispel many of the doubts and much of the superstitious awe which surrounds some children's (and adults') approaches to scientific phenomena. Certainly, one must respect the works of science and the minds of the men who have created these marvels, but one must never be overawed and superstitiously worshipful of such works and men.

BEHAVIOR PATTERNS RELATED TO FIELD TRIPS AND AUDIO-VISUAL EXPERIENCES

There is, of course, another set of major values to field trips and to audio-visual experiences, the values which derive from learning responsibility, from learning how to study a phenomenon at first hand, from learning to get along in a non-school situation which is organized differently from the regular and usual classroom procedures. After all, taking a bus trip to a museum or a factory, spending a day visiting, having lunch away from the

school cafeteria or schoolroom, meeting new people and new situations, all such experiences are learning experiences and require special work and preparation on the part of both the teacher and the children. And even the showing of a film or a filmstrip requires different kinds of behavior and new kinds of learnings from a group of children. School is for learning and it is for learning in many new and varied situations. Developing skills and attitudes necessary for these kinds of learnings is also a very important function of the presentation of field trips and audio-visual experiences to children.

SELECTING AUDIO-VISUAL MATERIALS AND FIELD TRIPS

Since field trips and audio-visual materials have such an important and such a specific part to play in the school curriculum, preparing for their use and planning their place in a unit require thorough attention. In order to use these materials wisely, the teacher should know what materials are available in the area. This means, in the case of films, that the teacher examines the film catalogs for possible films and filmstrips appropriate to the unit being planned. It means, further, looking for reviews of these materials in such annotated lists as the one that appears in Chapter XIII and, if possible, previewing the film when the original unit plans are being made. This early previewing is not always possible, but in such an event, the teacher should certainly preview the film before showing it to the class. It is even possible that he will plan to show a particular film, order it, preview it, find it unsatisfactory, and send it back without using it in class. A film should *never* be shown to a class group without first having been examined by the teacher.

It is wise to be continually on the lookout for new, interesting, and appropriate audio-visual materials. Keeping personal review

notes of films, filmstrips, records, and tapes is a very good practice. Such notes do not need to be elaborate. They can be kept on three-by-five file cards with a few descriptive comments, something like this:

Topic: Living Things *Date:* 10/60

Title: BEAVER DAM

Source: State University Film Center

Review: Good for primary grades. It shows beavers living, working, and playing around their dam.

A file of such cards along with any comments which the teacher wishes to make after each showing of the film is not only a valuable aid but really a necessity in planning.

Audio-visual materials may be used in a variety of ways. There is no reason, for example, why an entire film or filmstrip needs to be shown to a class. Only those portions which are appropriate need be shown. Or if it seems better to show the entire film so that the children can get a continuous story, then there is no reason why portions of the film cannot be repeated. Showing a film twice, with discussion between the two showings, is often a very good way to fix its information in the children's minds. Another technique in the use of films is to show the film without the sound and have the teacher provide the narration, replacing the sound track with his own explanation. In this way, a teacher, knowing the children and what they understand, often can explain the phenomena being shown in a film much more effectively than the original sound track. Filmstrips too should be used only as they pertain to the work being done by the class. Using five frames of a filmstrip, and using them effectively, is much better than trying to use all twenty-five or thirty frames just to show the children the remainder of the film. A good practice with filmstrips is to use those frames which are appropriate for the class

lesson and then keep the projector and the filmstrip in the room for a day or two and allow the children to see the remainder of the strip during their free time. When only two or three children are involved, this can be done in a corner without darkening the entire room. There are small filmstrip viewers which can be used for this purpose. If such a viewer can be kept in class at all times, then filmstrips can be used like other reference materials, and small groups of children can find information from them whenever they need to do so.

In the case of field trips, a knowledge of the potential resources is even more essential than it is in the case of audio-visual materials such as films. Without knowing the community and its resources, the teacher is resigning himself to using no field trips and thus to eliminating from his teaching techniques a most valuable aid. Again, a file of such resources is a useful tool. Such a file can be made by a single teacher or it can be the composite of the information on the community and its resources as gathered by the entire school staff. Regardless of who prepares it, it is well for the file to note the place to be visited and then state what can be seen there and what can be learned.

Things to see	*Science principles illustrated*
1. Local farm	
1. The breeding and raising of animals.	1. Men use animals to provide them with food, clothing, and power for work.
2. A pasteurizer.	2. Heat can be used to destroy many of the harmful bacteria in milk.
3. A cream separator.	3. The principle of centrifugal force can be applied in making useful machines.

Things to see	*Science principles illustrated*
4. How the land is prepared for tilling and how crops are cared for.	4. Through the use of sound conservation methods the yield of the land can be increased and the worth of the land as an agricultural resource can be maintained and even increased.

II. The power station

1. The source of fuel supply.	1. Coal, oil, waterfalls, or nuclear materials provide men with usable power.
2. The turbines and generators.	2. The energy stored up in the prime source (coal, for example) can be transformed through the use of machines into usable power (electricity).
3. The control grids of the power district.	3. Through the use of various instruments and appropriate maps of the district, the workers at the power station can provide the necessary power for the entire district.
4. The automation aspects of the power station.	4. New means of control and new kinds of instruments (closed circuit television from the boiler to the control room, for example) keep the number of workers needed to run the power station to a minimum.
5. The use of water in the production of electricity.	5. Water is used either for producing the steam to run a turbine or for the direct operation of a water turbine.

Things to see	*Science principles illustrated*
III. THE RADIO AND/OR TELEVISION STATION	
1. The various machines which are used in broadcasting; for example: microphones, amplifiers, and antennas.	1. A radio station uses machines to change sound waves into equivalent electric waves and also produces waves which can be transmitted over long distances.
2. The operation of the camera.	2. Light energy can be transformed into electrical energy by the television camera.
3. Transmitters.	3. The sound and the picture are each transmitted over a different frequency. Each, in fact, is sent out over a different radio signal.
4. The press and wire facilities of the news section of the station.	4. Teletype and telephoto machines connect all of the country and carry news from all over the world to the local radio station and newspaper.
5. The antenna system in relation to the entire station.	5. The radio signals are sent out from as high a point as possible because frequencies used by television are line-of-sight wave lengths. The higher the antenna, the further signals can be sent.
IV. THE GARAGE	
1. The machines which lift and move cars and trucks.	1. The hydraulic jack uses a small amount of force to lift a large amount of weight. The chain lift uses pulley systems to provide great mechanical advantages.

Things to see	*Science principles illustrated*
2. The arc and spot welding operations.	2. Combinations of different gases can provide heats which are great enough to melt metals. Electricity also can be used to melt metals.
3. The operation of the gasoline engine.	3. A gasoline engine uses gasoline to make explosions. These controlled explosions are used to provide the mechanical energy which operates the automobile or truck.

There are many other resources in every community. The local factories offer varied opportunities and each factory has its own possibilities. Newspaper plants, mining operations, grocery stores, harbor facilities, food processing plants, shoe repair shops, bus and railroad terminals, airports, weather stations, military bases, and, far from least, the school grounds and buildings themselves—all of these facilities can be explored and the trip possibilities examined, always keeping in mind the science principles which can be demonstrated through the trip.

In addition to the information about what science material can be gained from the trip, teachers need to know several other details. For example, it is important to know the person with whom a trip should be planned. The time when the trip is taken can make the difference between a successful experience and a complete failure. Imagine a trip to a hydroelectric station. All the children are primed to see the waterfall running the generators. Then, when the group arrives, they find that the station is not in operation at that time. Going over details about when to come for a visit, how to get to the plant, what people to use as guides, these can make the difference between a successful trip and a failure.

PLANNING THE TRIP WITH THE GUIDE

Once the general information is availablo through some kind of a filing system, teachers can use it for planning and organizing specific trips. Of course, this kind of a system necessitates constant revision and evaluation of the information so that potential trips can be kept up-to-date. But, assuming that the file is up-to-date and ready for use, the first step in planning a trip is to talk to the correct person about bringing the children to visit the plant. This person will vary from place to place. In a large government agency such as a military installation or a major weather station, there is always an information officer in charge of arranging such visits. A large factory will have a public relations officer. A small factory or a local business will have a manager or an owner who will help the teacher arrange his trip. In each case, the teacher should plan carefully with the proper person.

It goes without saying that plans will include the necessary mechanical details of the trip, such as where to park cars, and how to arrange for meals and for drinking and toilet facilities. These details are important, but they are only one part of the total trip. The major planning concerns the educational aspects of the trip which should be worked out carefully with the guide. In the first place, he must know the purpose of the trip and see how this purpose fits into the over-all objectives toward which the group is striving. Unless the guide understands the purpose clearly, he will not know what aspects of his plant are of concern to the children. Furthermore, a person connected with a plant, or factory, or farm, or government agency is so proud of his facility that he is anxious to try to show all of it to a group of visitors. This must be avoided. Trips should be for specific purposes. The children should know these purposes. The teachers should build the plans around these purposes. The guides should be well aware of these purposes.

Once the guide has the purpose of the trip clearly in mind, he can help the teacher find those aspects of his plant which will best illustrate what the children are learning. As the teacher goes around the plant beforehand with the guide, he can pick out those aspects which seem most important to him and can ask that these be stressed when the children come. But the teacher has another job to do too. He must help the guide explain in simple and clear language what is being shown. Guides are often specialists and they may forget to drop their technical language when talking to a group of children. In the planning session, the teacher can help the guide find appropriate words for explaining the operation of the plant to his group of children, and can predict possible questions the children will ask. Finally, specific time should be set aside for a summation of what the children have seen. If it is at all possible, this summation should take place in a comfortable room where the children can sit down and where there are a blackboard and other facilities for reviewing the trip. Time should be allowed at this point for the children to ask questions.

PLANNING IN THE CLASSROOM

The only purpose for taking a school trip is to further the education of the children. This means that the children must be thoroughly prepared for any trip that is to be taken. The children should know the educational purpose of the trip; that is, they should know why the trip is being taken and what they can expect to learn. The children must understand the relationship between the trip and the unit of study as it is being carried on in class. This relationship must be very clear if the trip is to be a school learning experience. School trips are different from family outings in this major respect. A family outing is primarily an opportunity for a family to enjoy something together. The edu-

cational experiences of such outings are incidental. A school trip, on the other hand, is an educational experience first and foremost. Of course, the children should and will have a good time on the trip. But we take children on school trips as part of a planned program of learning. Unless this is the purpose of the trip, and unless the children know this purpose, then the trip should not be taken.

An important part of the trip experience can be the pupil participation in the planning and organizing of the trip. This planning phase of trips offers excellent possibilities for giving the most able children some extra opportunities. These children can go along with the teacher on the preliminary trip to help set up the itinerary for the regular trip. Such able youngsters can be counted on to seek out the points of interest, to recognize many of the unusual features of the trip, to see and note those aspects of the trip which will cause difficulty to children. Using the help of these children will not only give them some additional experiences but will also benefit the entire class.

Once the pre-trip has been taken, the class must plan for the regular trip. What questions are to be answered? What items should be particularly noted? What behavior is expected and why is such behavior necessary for the success of the trip? Questions like these need to be part of the children's preparation. This preparation can be carried on through a variety of techniques depending upon the age of the children going on the trip and on the place to which the trip is taken. For an older group going to a museum, for example, the class may prepare a duplicated sheet of instructions and questions so that each member of the class will know what he is looking at and what he is looking for. Such a list of questions can very well grow out of the experiences of the preliminary planning group and its report to the class as a whole. On a trip to a factory, the children can discuss in the planning session the kinds of questions which they want

answered by the person who is going to take them around the factory. With younger children, the plans may include a specific assignment for each child so that one child will find the answer to one question and another to some other pertinent question. These answers can be brought together later in the class summary of the trip.

This planning in advance, along with the trip itself and the summary of the trip, serves also to develop the maturity of the children. Learning is more and more possible as children become responsible for their own behavior and their own learnings. And science trips can be used to develop this area of personal responsibility as well as to further the specific goals of elementary school science.

THE TRIP ITSELF

During the field trip itself, the teacher's role is to act as the interpreter for the children. It is most important that he be observant of the many things that go on. He must hear the questions that the children ask; he must watch their faces and see when they understand and when they are puzzled. It is only he who can stop the guide and ask for further explanation. The children may perhaps be too shy. Of course, careful planning will have eliminated many of these pitfalls. But still, sometimes the guide's language will become too technical, and then the teacher, recognizing what has happened, must make sure that the children's questions, either expressed or implied, are being answered to their satisfaction. Finally, the teacher must help the guide with his presentation. Most guides are not teachers and may not know the techniques involved in good presentations. So, for example, the teacher walks along with the guide and makes sure that the children are gathered around him before he

starts to speak. Walking in this way also allows the teacher to set the pace and thus wait for the children who may fall behind. The teacher can also allow the children to do some of their own discovering. But, if the children do not find what may be an important link in their understanding of what is being studied, then the teacher is there to make sure it is pointed out and understood. Finally, the guide should help sum up what has been seen. Here the teacher makes certain that the information is covered point by point and that the children are given an opportunity to ask questions about what they do not understand.

SUMMARIZING THE TRIP

Once the trip has been taken, there is still much to be done if the total experience is to be worthwhile. The trip must be summarized and evaluated and fit into the total unit. A good procedure for summarizing a trip experience will have four parts. First, the significant factors of the trip should be examined. What did the trip explain and how did it explain these things? What were the high points of the trip? What were the unusual things which impressed the children? The second step is to determine the extent to which the trip answered the questions for which it was taken. If the trip was intended to show the functional relationships between fuels and power, can the children answer the questions which they formulated beforehand on this topic? The third part of the summary is to allow for consideration of new questions and new information which the trip has brought to the children. In addition to answering old questions, a good field trip should raise new questions both related to the materials the children are studying and in areas that are not necessarily tied in directly with what is being studied. Thus, a field trip to a museum may have as its prime purpose finding out about the ways in which various animal groups live. Yet, if the children in their

free time at the museum become interested in geologic materials or dinosaurs, or fossils of plants, they must have a chance to discuss and summarize these findings too. Perhaps these incidental interests may lead to further units of study. Finally, the summary of a *field trip reviews and fixes the relationship* between the field trip and the unit of study being carried on. Unless and until this kind of summary is made, the field trip is not completed.

RESOURCE PERSONS IN THE CLASSROOM

For the most part, the discussion so far has concerned field trips and audio-visual materials such as films. Many of the functions which are served by these two kinds of educational experiences can also be served by bringing an expert or resource person into the classroom. There are innumerable persons in any community who are both happy to come and bring material to the children in school and who also are capable of giving the children a very worthwhile experience.

Bringing a resource person into the classroom often serves the same functions as taking the children to see some special phenomenon. The resource person brings an authoritative word on a problem which the children are studying. He can tell them about some aspect of science, because he is a scientist. He can tell them about flying airplanes because he is a pilot. He can tell them about building bridges because he is an engineer. Again, however, it must be remembered that the function of the resource person is to add to the work *that is being done in the classroom.* He is not brought in to amuse or amaze the children. He comes to help teach specific materials to the children.

There are a few simple things which a teacher can do to make the visits of such resource people more successful.

1. Remember that the expert is not a substitute teacher. He is bringing information, but the teacher must be there to help him get his information across to the group.

2. Be sure that the students know why the expert is coming and that they are ready to learn what he has to present.

3. Limit the material which the expert is going to present. He may know a great deal about chemistry if he is a chemist, but he cannot cover all of chemistry in the course of an hour's talk to a fifth grade. The resource person should work on one topic and do it simply and basically.

4. Use what the resource person brings to the class as one part of an over-all unit of work. Such people should be brought to class only when they fit in with the work of the class.

Quite aside from the value of the information which such resource people can bring to a class, there are other important aspects to visits by experts. For one thing, here are important people coming to help the children. Here are "real scientists!" Best of all, such people are not hard to find. Every school and often every class has resource people among its parent body. Remember, "expert" is a relative term. There is an old joke that every man is an expert as long as he is more than fifty miles from home. A good custodian is an "expert" on what is in the school basement. A high school science teacher is an expert on plants and animals not only for his own students but especially for elementary school children. A neighborhood doctor is an expert on health. These are the people who can help children learn.

RADIO AND TELEVISION IN THE CLASSROOM

Almost since the first use of radio, many teachers recognized the educational potential of this medium. Many stations and many

school systems organized radio programs for use in the classroom, and among these programs were many on science. In essence, of course, these programs were experts coming into many classrooms at once. They had distinct advantages and distinct disadvantages. On the one hand, some very competent experts could be brought to school, and they could have large, even enormous audiences. For another thing, in a large school system, through the use of radio, all the children at a given grade level could receive instruction on the same science material at the same time and in the same way. School administrators could be sure that there would be no repetition that was not planned and that all the material which they felt should go into a program could be included. Finally, radio education could be comparatively inexpensive. One expert teacher could be used to instruct many classes at ono time. But disadvantages were many. For one thing, not all third grade children are ready for the same science materials at the samo time. For another, children who listen to a radio program and whoso science teacher is miles away in a radio studio cannot ask questions about things which they do not understand. And even more important, teachers cannot watch the children's reactions and stop and repeat when necessary or go back to a related point which is appropriate for a given lesson. Theoretically, classroom teachers were supposed to serve these functions, and often they did. But just as films or live experts brought into the classroom could not replace teachers, so radio could not either.

Television now has come to school. It is, certainly, a marvelous educational tool. Not only can experts be brought into the classroom through the medium of sound, they can now be seen as they work. Good camera techniques can often bring an experiment or a demonstration closer to the children than if the demonstrator were right in the classroom. Television programs thus have very fine possibilities for science teaching. Children can watch science demonstrations from "ringside" seats and can

hear explanations of science phenomena given by experts who not only have a thorough understanding of science but who also know children and how to teach them. Furthermore, television has another important use in the classroom. Through the medium of television, children can observe history as it is being made. And since so much science history is being made right now, both their great curiosity about science and their interest in the world around them is served through this new educational tool.

But again, all the difficulties in radio are inherent in television programs. Education is a very personal and active affair. Each child really must be placed in a position where he himself learns. And the function of the teacher is to see that he does this learning. The teacher motivates and summarizes and repeats and he recognizes when he can go on with the lesson and when he must go back and review. And for this kind of teaching, neither radio nor television lessons are enough.

Thus, radio and television can be used, and used effectively, to bring experts into the elementary school science classroom. But to do so, the classroom teacher must still be the center of organization. It is he who must plan how the program will be used. It is he who must watch the children's reactions and ask the pertinent questions and review the lesson. In short, these programs are of the same character as films and other audio-visual devices and should be used in the same ways.

Summary

Field trips, audio-visual materials, resource people, radio and television programs—all are important ways of carrying on active learning experiences with children. Such experiences give the children a chance to use many of their senses in learning. But the important

thing to remember is that such experiences are only means to an end. In and of themselves they have limited value. It is different for out-of-school activities. At home, in a camp situation, in a club program, these kinds of experiences can have worth for recreation and for amusement. But school is for specific learnings, and field trips, resource people, audio-visual materials, radio and television *must serve these educational ends or they should not be used.*

Since these kinds of experiences have such important educational uses, they can be employed often if their functions are kept clearly in mind. Use these techniques when:

1. A set of direct experiences are needed in an area to help the children build background for further study of the subject.

2. A new set of interests can and should be developed with the children or old interests should be extended and expanded.

3. The principles that the children have learned as small but separate wholes can be put together as a larger and more complete picture.

4. A field trip or a film can help children understand and verify for themselves some phenomena which previously were entirely in the realm of the theoretical.

There is an additional value to these experiences which should be noted. Field trips and films can be very useful in helping children see and understand the relationships between science principles and concepts and other aspects of the curriculum. *As children go out on a field trip to a factory, they cannot help noting the social science* aspects of their trip. In like manner, integration with other areas of the curriculum also can take place on science field trips. But this, so to speak, is an added dividend. Primarily, the field trip and the audio-visual experience is a good way to explain certain science principles and concepts, and should be used for that.

X CULMINATING ACTIVITIES IN ELEMENTARY SCIENCE

A SOUND elementary school program should be a vast continuum with no absolute beginnings and no absolute ends except entrance into school on the first day and graduation on the last. Each item that is learned, each concept that is formulated, each unit that is completed should lead on to new learnings, to new questions, to new and wider horizons. But getting the optimum from a learning situation calls for a variety of summarizations so that the transition from one unit to the next can be smooth and effective. And one of the most useful of these summarizations is the *culminating activity.*

A culminating activity is the natural and direct outgrowth of a unit of work that has been studied by the children. It can be a play which the children produce or it can be an exhibit which they prepare. It can be a science newsletter or a report. It can be material for a science fair or it can be a science assembly program given by the children. But regardless of the form it takes,

it must be directly related to what the children have been studying and it must be clear to them, to the teacher, and to everyone else concerned that the activity grows out of and is dependent upon what the class has been doing. Any of these culminating activities should have two major purposes. First, such activities should serve to fix the learnings that the children have achieved. Second, they should give the children some incentive to go on from the questions and problems which they have mastered to new and broader problems.

CRITERIA FOR ASSEMBLY PROGRAMS

By far the most important type of culminating activity is the assembly program. The assembly provides the opportunity for a group of children to present either to the whole school or to some part of the school, materials, in this case science materials, which they have been studying in their class. For example, a group of fourth graders has been studying about conservation. An assembly can be built around this subject. Deciding, first, whether this should be done at all and, if so, which classes should be invited to the production necessitates answering two questions: Will the children who have studied about conservation profit from putting on such an assembly? Assuming the answer to this question is affirmative, the next question is: Which groups of children can profit from attending such an assembly? Answering the first question means examining such problems as: What is the best way for the group to summarize what it has learned? Perhaps a series of reports would be best. Perhaps an exhibit would be more appropriate. Perhaps no formal culminating activity is necessary for this unit. Activities of this kind are time consuming and the teacher must make certain that the time and effort spent on such an activity are worthwhile from an educational point of view. Furthermore,

one must decide whether the program can grow naturally out of the work that the children have been doing. Unless it grows from their work, and unless the children can see this relationship, the program is liable to be nothing more than busywork for them. Then there are such questions as: Is the group ready for the responsibility of putting on a program of this kind? Can a sufficient number of children be involved in the program to make it a worthwhile experience for the whole class? While these last two questions are not directly related to the science unit under consideration, they are directly related to the developmental level of the group; learning, as has been pointed out, is not compartmentalized. A subject like conservation can make a fine assembly program, but unless the fourth-grade children are ready for the responsibility of such a program and unless they can profit from it, putting on such an assembly is worse than useless.

The second question—Which groups of children can profit from attending such an assembly?—also has various ramifications: Can the primary classes understand enough of the presentation to make it profitable for them to sit through such an assembly? Is this the sort of program which should be presented to all the children in the intermediate grades or should it be given only for the other fourth grade classes? Should parents also be invited to the assembly? Should this be a special program given just for the parents of the group? The answers to all these questions must be determined on the basis of the needs and readiness of the class in particular and the school as a whole. It is probably a good rule of thumb, however, to keep programs for primary grade children simple and short. Those for older children can be more extensive. But the two criteria—the learning values for the children who give the program, and the learning values for those who see it—should be taken into consideration and must become the basis for decision.

A SECOND GRADE ASSEMBLY ABOUT CHICKS

Assuming that these criteria have been met, how should a teacher go about planning an assembly program? This is the way one teacher used an assembly. Miss Young had an enthusiastic and spirited group for her second grade class. They spent six weeks studying about chicks and had the exciting experience of incubating eggs which came from one of the farms in the neighborhood. Having had some previous experience with this kind of situation, Miss Young had been very careful to make certain to use fertile eggs. In fact, she used eggs from a hatchery so that she was positive of results. And on the twenty-first day, according to schedule, the eggs hatched and there were seven baby chicks. The chicks had started hatching before school opened and when the children arrived two were out and the others were pecking their way through the shells. The excitement was keen. "Can we pick them up?" "Oh, look. That one is all fluffed out." "Gee, they're cute. Can I bring my sister in so she can see them?" "Let's show them to Mr. Smith [the principal]." "Hey, I'm going outside and tell everyone to come in and see our chickens."

Here, Miss Young stepped in. "Hold on there, David. Let's not invite people in here yet. Why don't we make some plans so that we can have all the children come and visit our chicks?" With some difficulty, the children came away from the little incubator and sat down to plan how they might share their good fortune with others in the school. While Miss Young had not made specific plans for having the children put on an assembly and bring the information they had gathered to the other classes in the school, she had known that it was possible that such a program might evolve from their work. With such an exciting project going on, it was inevitable that the children

would want to share their findings. The decision that needed to be made concerned the extent of such a sharing program. This would be the first experience for these second graders to present information to another class, so it seemed wise to limit the audience to the children in the other primary grades. Exceptions were made so that a few of the older brothers and sisters from the upper grades could come. This experience also had possibilities for use in explaining the science program of the second grade to parents which Miss Young intended to exploit separately.

The children, with Miss Young's help, planned a simple program for the primary grades. The program would include the demonstration of several of the science principles which were involved in the unit. One group of children would explain the thermometer and how it operates. They would set up an air thermometer using colored water for the liquid and show how the position of the liquid could be changed with the warmth of their hands. They also had a large, clearly marked thermometer which they got from the science storeroom and, using a large pan of ice, they could demonstrate the falling and rising of the thermometric liquid (colored alcohol in this case) as the thermometer was put into the ice water and then removed from it.

A second group of children would demonstrate the workings of the thermostat. The device which the children had used in their incubator was a simple one which Miss Young had obtained from a farm supply house in the neighborhood. When the thermostat was cooled, it made contact in an electric circuit and lit a bulb which warmed the eggs. As soon as the desired temperature was reached, the thermostat automatically broke the circuit and the bulb went out. What the children planned to do was to show this bulb and thermostat circuit and explain its purpose in the incubation process.

A third group would explain what the children knew about the incubation process and show a series of their drawings to illustrate the work of the unit. The fourth group would show the chicks and tell about how they were being cared for, what they were being fed, why they were being kept warm with a lamp, and what the children planned to do with the chicks. They were to be given to one of the children who lived on a farm. This last point was important because Miss Young wanted to have the chicks removed from school at the proper time without too much fuss.

After working out the details of the program, the children rehearsed what they were going to do. Miss Young kept the program very simple. There were no lines to memorize, no formal parts to be played. Each of the participants was thoroughly familiar with the principle which he was to explain. With this knowledge, he was able to make up his own words for the explanation. This very technique was an important part of the summarization and an important way in which Miss Young was able to determine to what extent the children knew and understood the concepts which they had been studying. The rehearsals and the program itself were held in the classroom and no formal stage was used. Every child had some part and no child had a large part.

Miss Young decided to allow the children to present the program to the parents also. She realized, of course, that a presentation for parents at 2:30 in the afternoon would really mean an assembly for mothers. She would have liked to have the fathers too, but she felt that bringing the children to an evening meeting when fathers could be present would make too much of the program. Miss Young's purpose for holding this meeting was to show the mothers, and those fathers who could come, some of the science work that the children were doing. The opportunity to demonstrate to their parents their

knowledge of several science principles could do much for the children's self-esteem.

A SIXTH GRADE ASSEMBLY ON FIRE PREVENTION

Another example of the use of assembly programs was carried out by a sixth grade that had been studying combustion and fire prevention. The sixth grade assembly was also the opening event in the observation of Fire Prevention Week. It was presented to the intermediate grades only, because the program was too long for all the primary grades children and the material to be presented was too difficult for many of them to understand. The program was an explanation of the factors necessary for combustion, of the ways in which a fire might be prevented by keeping these factors from being brought together, and of the ways in which a fire might be extinguished by eliminating one of the necessary elements. The children had four principles to illustrate in their assembly:

1. There are three things which are necessary for combustion or burning: fuel or something to burn; oxygen or air; ignition temperature or enough heat to start the fire. All three are necessary for combustion.

2. There are many ways in which you can get heat; for example, you can get it from friction, or from electricity, or from light, or from chemicals. This changing of friction to heat, or electricity to heat, etc., is called *transforming energy from one form to another.*

3. Fires can be prevented by making sure that the three factors necessary for combustion do not come together.

4. Fires can be controlled and extinguished by removing one of the necessary elements. Most often this is done by removing the fuel or by removing the air from around the fire.

In order to illustrate these principles, the children worked out a series of demonstrations which they used for their assembly. The children, working in groups of twos and threes, planned and organized various demonstrations; for example:

1. Two boys, using a bow and spindle obtained from their Boy Scout Troop, demonstrated fire making through use of friction.

2. Also using scout equipment, two girls and a boy made fire with flint and steel.

3. Another group made a fire with ground-up potassium permanganate and a few drops of glycerin, using the chemical reaction as the energy source.

4. Using sunlight and a burning glass, several children showed that light energy could be transformed into heat energy to start a fire.

5. Using a dry cell and a spark coil which they borrowed from the high school science laboratory, several children showed the relationship between electricity and heat, and used the resultant heat to start a fire.

6. Using materials such as oily rags, imitation cigarettes (the children in this group had a wonderful time with candy cigarettes for props), and newspapers, a group put on a skit about fire prevention in the home.

7. Two boys who were interested in electricity, prepared a simple demonstration to show what a short circuit is and how a fuse prevents fires by breaking an electric circuit which is overloaded.

8. A group made a simple fire extinguisher out of sodium bicarbonate and vinegar and, using this apparatus, put out a fire which they built in a metal waste basket.

All of these demonstrations were woven together by one of the

children, who gave the theme of the program and emphasized the principles being explained. The narrator also stressed the safety aspects of each demonstration and as he talked about safety the children who were giving the demonstration showed their own safety precautions. They showed the asbestos mats on which they worked. They showed how they were careful about keeping their clothing away from the fire. They showed all the precautions they took in order to maintain safety.

The final section of the assembly was a presentation of safety rules with fire. Here a group of children showed the correct ways in which to store combustible materials. They reviewed the skit about safety around the home. They told what to do in the event of fire. They explained what to do if a person's clothing caught fire. They talked of the danger to forests and wooded areas from carelessness with either camp fires or with burning matches, cigars, or cigarettes.

In addition to the children's program, the local fire department put on a demonstration of their apparatus during the week. Using the school playground, they showed how various kinds of fire extinguishers work. They showed asbestos suits and other fire-fighting clothing. They demonstrated various nozzles and explained their uses. And they showed the children how gas masks are used in fire fighting. This was a very impressive part of the program for the children since they were allowed to try on the gas masks. The firemen also loaned the school various pieces of apparatus (extinguishers, nozzles, hose sections, and several other items) which were displayed in the school exhibit cases.

The firemen's program was closely tied in with the assembly which the children had conducted. The fire chief had come to the assembly and had been most helpful in the entire unit. When the firemen demonstrated the professional apparatus, the chief, who

was explaining what they did, referred over and over again to the principles which the children had explained in their assembly program. As the professional soda-acid extinguisher was being demonstrated, he explained its similarity to the bicarbonate-vinegar extinguisher which the children had made and used. When the carbon dioxide-foam extinguisher was demonstrated, the chief pointed out how this extinguisher eliminated the oxygen from the fire and thus put out the fire. This was a very exciting demonstration because several of the children were allowed to release the trigger on this extinguisher and direct the stream of foam onto a small fire. Finally, the firemen demonstrated some of the first aid techniques for fire injuries and stressed the importance of immediately reporting fires to the fire fighters. All the children were given small stickers with the fire company's telephone number and directions on how to report a fire.

Assembly programs like these not only serve to clarify and summarize the information which the children have gathered in science but they also give the children opportunities to gain recognition for what they have achieved. When the sixth grade children wrote a letter of thanks to the fire chief, they received in return a long letter which praised their work and which appointed them all "Firemen, Junior Grade" with badges which they wore with pride. They knew that they had done a fine job. In the same way, the second grade children gained status and consequent maturity from the knowledge that their work was appreciated and understood by their peers and parents. Providing the children an opportunity to gain recognition for what they have done is an important function of a culminating activity.

EXHIBITS

Culminating activities in the science program can also be built around exhibits. Exhibit cases in the hallways of the school are

Amphibia," the "Age of Reptiles," and the "Age of Mammals." Using this information, the children prepared the dioramas. Papier-mâché became mountains; tin pans painted black became tar pits; twigs and moss and grass became giant trees and ferns. And in the shade of these forests, scale models of dinosaurs and other beasts roamed as the children imagined they would have done thousands and millions of years ago. All their work, all of their study was thus used for preparing the exhibit. Not only did they summarize most effectively what they had learned, but the exhibit was enjoyed by the other children and also by the parents when they visited the school for a grade-parents meeting.

SCIENCE FAIRS

Closely related to exhibits are science fairs. They too can serve as excellent culminating activities. But science fairs, while similar both to assemblies and to class exhibits, have certain special characteristics and uses. In the first place, they are much more suitable for projects by individual children and by small groups of children. Over the course of the school year, children from every class will have worked on small group projects. The fair is a good time for displaying them. The exhibit of a group of children which shows the community's water system, the exhibit which shows how the water is purified, the display of the water cycle and its meaning for men, all of these can be part of a science fair exhibit. Then there is also a place for the science work of individual children. Science clubs encourage the children to work on individual interests and science fairs are media through which such individual work can be displayed.

But fairs can be used for another purpose. They can serve to show all the children and the entire staff the scope of the science work that has been carried on in the school during the year. This

example, one useful device for organizing a fair is to build it around a theme. One such theme that has had a considerable amount of success is "Science in Our Town." In this kind of an exhibit, the displays indicate the ways in which science has had an impact on various phases of life in the community and the principles of science which underlie each of the applications shown. Thus, there might be an exhibit of the various transportation facilities of the community along with the explanations of the science principle underlying each of the modes of transportation—cut-out models of Diesel engines, diagrams of gasoline engines, models of trains, models of planes, drawings of bridges, maps, and the like. Another exhibit might show different kinds of industry in the community along with the explanations of the machines used in the various plants and factories. Still another might concern itself with the agriculture of the area, or with the electric power plants, or the sewage disposal system. The younger children, if they are to be involved in the program, might work on the plants and animals of the community, or on the use of electricity in the homes. There are, of course, many other possible themes: "Transportation Through the Ages," "Communication," "Flight," "Power and Energy," "Health," "Conservation," "Frontiers of Science"; and all lend themselves to projects which can be done by classes, by small groups, or by individuals, and they can be done with varying degrees of maturity. Always, there can be a special section devoted to individual and group projects which fall outside the theme, but which are worthy of display. Thus, all the children can have a part in the program and all can engage in creative science work at the level of their abilities.

WRITTEN REPORTS AND ARTICLES FOR THE SCHOOL NEWSPAPER

There are times when the best kind of culmination to science work comes in the form of the written report. Such reports can

be of real service to children who have worked on individual projects. A written report is, after all, a means of summarizing the information that one has gathered about a topic. At the elementary school level such summarizations are most valuable to the reporter. For this reason, they should be used to help the children not only in the area of science but also in the area of reporting, in this case, science reporting. This objective, the analysis of a science problem and its posing in a succinct and lucid statement, should be made clear to the children. They must know that the reason for writing reports is as much to learn to write creditable science statements as it is to summarize the science that they have learned. Too often, children are not informed of this purpose and, consequently, can see no reason for producing their reports.

Of course, science stories are newsworthy and should be used in the school newspaper. Again, however, the function of a school newspaper, particularly an elementary school newspaper must be kept in mind. The school newspaper is mainly for the writers and their parents. To get one's material printed is very important at any time. When a person is seven, or eight, or ten years old, having a story printed is even more impressive. Children will work very effectively for such a goal, and they can and should be held to as high standards as they are capable of attaining. Like everything they prepare for the newspaper, the science stories should be done with great care. The facts should be stated accurately and simply. The generalizations should be properly drawn. All of these things children must learn how to do. Thus, as well as teaching the science materials, teachers instruct in the writing of science reports.

Summary

Every science unit needs to be summarized as it draws to a close and, often, culminating activities in the form of assemblies, exhibits, science

fairs, and written reports can be useful for this purpose. The culminating activities always must grow out of the work that the children have been doing in class. When such activities are a natural outgrowth of the children's work, they are effective learning devices. The following criteria are suggested for planning and using culminating programs:

1. The activity must be directly related to the work that the children have been doing.

2. The activity must summarize the high lights of what has been studied and must be a device through which the producing group can state its learnings.

3. The activity should be carried on through the most effective medium available. These various media include, among others, assemblies, exhibits, science fairs, and written reports. At times, culminating programs carried on by a class can be related to whole school, city-wide, state-wide, and even national celebrations and observations of appropriate science subjects.

4. Programs should be presented only to those children who can profit from seeing them. If the audience is too young or, conversely, too sophisticated for the material being presented, the resultant values are diminished. Teachers must consider not only the intellectual maturity of children, but also their physical and emotional maturity. A group may be intellectually able to understand a program, but may not be able to sit still for the time required. All such factors need consideration when the audience is chosen.

As such criteria are considered and brought to bear on the planning, organizing, and producing of culminating programs, several values accrue. In the first place, and by far the most important, are the values to the children who put on the programs. The children will grow both educationally and socially from such well organized programs. Then there are the values which accrue to the audiences. Other children too can grow intellectually and learn much from attending these assemblies or examining exhibits. And there is still another value. Culminating activities are often very useful in bringing an understanding

of the work which the children are doing in science to their parents and to other adults in the community. This final value is the extra dividend that comes along free as the other values are met.

EVALUATION IS MORE
THAN JUST TESTING FOR FACTS

Can they apply science principles to real situations?

Can they use tools?

Can they express on paper what they have learned?

XI EVALUATING CHILDREN'S GROWTH IN SCIENCE

THE key words in teaching are "why," "what," "when," "how," and "how well." These words are the determinants of the tasks of education. The "why" is the philosophy of education upon which the school is based. Generally speaking, such a philosophy in American society is the *responsibility of the community as a whole* and not just the responsibility of the teachers alone. But the other four functions, the "what," the "when," the "how," and the "how well" are specifically the responsibilities of teachers. Three of these four major tasks of teaching have been considered so far: first, what should the children learn in the area of science; second, when should the children learn various science materials; and third, what are the most effective means of helping them learn the science. The fourth important responsibility for the teacher is to ascertain how well students are attaining the goals established for the program. This careful appraisal of the student's progress toward the objectives of the curriculum is referred to as *evaluation*.

Thus, evaluation is the complex system through which a teacher establishes judgments and makes decisions about his students, his program, and his teaching. First, then, must come the examination of an effective evaluation program and a consideration of the characteristics which are inherent in such a program. Once such a statement is made, the techniques by which a teacher carries out such an evaluation program in elementary science can be established.

CHARACTERISTICS OF EFFECTIVE EVALUATION

An evaluation program begins with a statement of objectives. Right from the first planning of a unit and even before a single child has come into the classroom, the evaluation program begins. At the core of such a program is the clear definition of the goals to be attained. So, first, teachers must be clear about what their goals actually are. One of the common goals for teaching science has been stated as:

To develop the ability of the children to use the scientific method.

But just what is the "scientific method?" As has been pointed out, there are as many scientific methods as there are scientists. What this goal really is striving for is the development of rational attitudes toward the world. Clear objectives would delineate the purposes to be achieved and would define these purposes in sufficient detail so that everyone could understand them. Here are possible examples of such objectives:

I. To help children develop rational attitudes toward the world around them:

   A. To be able to identify superstitions

B. To be able to identify non sequiturs
C. To be able to identify sources of information and consider their dependability

II. To help children learn the techniques of problem solving:
A. To be able to state a variety of hypotheses
B. To set up plans for testing these hypotheses
C. To draw valid conclusions from these tests

A clear, detailed, honest, and, above all, realistic statement of goals is the first essential for evaluating an elementary school science program.

But such clear statements of goals are just the beginning. Actually, the big step comes in the way the goals are expressed. How they are stated can make or break the evaluation program and, for that matter, the entire program. Since learning is a modification of human behavior, what is needed is a statement of goals in terms of the way a student will behave after he has completed the science work being taught. Take a very simple example. One reason for teaching science is to improve the hygiene habits of children. This reason is perfectly valid and is one that has led to an important part of the elementary science program over the past fifty years.

The objective of health and hygiene has often been stated this way:

In order to live an effective and healthy life, every person should know the basic principles of science which underlie good health and good sanitation practices.

This is certainly a true statement. It is also a lovely—and useless—platitude from the point of view of the classroom teacher. Surely the teacher knows that a thorough understanding of basic biological principles is useful, perhaps even essential, for healthful

living. But how can he determine how effectively his students are using the information which is being taught to them in this important area of health and biology? The answer is that with such a statement of objectives, he cannot. With that kind of general and vague objective, evaluation becomes extremely difficult, if not impossible. In the end, the student just works for a satisfactory grade on an examination and gives only lip service to the attainment of the goal.

However, since education is the process of changing human behavior, and since objectives and goals need to be expressed in terms of pupil behaviors, teachers must find ways of stating such goals so that they can indicate these changed behavior patterns. Take the same example, science education and health. What kinds of health practices can nine-year-olds be expected to learn? What changes in behavior can be expected of these children as they undergo the experience of a well-planned unit on science and health? Being honest about this, one recognizes that many of the child's health practices are determined for him by the adults who influence his life. But there are areas where nine-year-olds can have control over their health actions. There are specific items in health habits which they themselves can come to understand and which, consequently, they can change as they achieve these new learnings. They can, for example, learn to get reasonably clean before they eat. They can learn to report cuts and bruises and have them cared for. They can learn to use a handkerchief and to cover coughs and sneezes. These are specific things which children can and should do. Such practices by the children, then, reflect the attainment of some of the goals of the science and health program. And, these kinds of goals can be evaluated. Does the child wash, or doesn't he? Does he cover his mouth and nose when he coughs, or doesn't he? In other words, the child's actions are one important part of the evaluation procedure. The first criterion, then, for the establishment of an evaluation program is the clear and realistic statement of objectives in terms of desired pupil behaviors.

Evaluation is more than just testing, even though the test is the most common evaluating technique used. "How do I evaluate the children? It's easy. I give them a test on the material that I have been teaching. Then, the test mark combined with their home work marks gives me the grade for their report cards." Certainly this is a familiar teacher. Everyone has met him. He carefully checks the homework and the tests. He records the grades accurately. But he uses the terms "measurement" and "evaluation" synonymously even though the two concepts are completely different. This is not surprising. Many are the teachers who feel that they are evaluating when they give written tests and record the results on report cards.

Testing—for factual information, for concept recognition, for many other things—is an important part of the evaluation program. From well-constructed tests a teacher can obtain much valuable data about the factual information children have absorbed. But using test marks as the sole criterion for evaluating children's progress toward the goals of an educational program is like judging the health of a child solely on the basis of his height, or his weight, or his shoe size. The inadequacy of such an action stands out markedly as soon as one considers that tests and test marks do not measure the varied activities of a classroom program and neither indicates the strengths and weaknesses of the individual pupils engaged in these activities.

In a science program, many methods of gathering information and evidence of pupils' progress are available and often these are methods much more appropriate than tests to the evaluation of phases of progress. A written test can hardly be effective for judging how well a student can use a microscope. Nor can a short answer test show his ability to state a problem. Then there are the student's attitudes toward his work, his willingness to improve, his concern for accuracy, and the finished pieces of work that he produces. All of these items show aspects of the student's behavior in the learning situation.

Every unit in science will require the use of a variety of methods for judging the pupils' competencies. In a unit on microbes, for example, the students should be evaluated on the facts they have learned, on the effectiveness with which they use microscopes, on the ways in which they can see and state problems, on the kinds of generalizations they can build about a topic like "Microbes and Health." And the appraisal of the growth of any one of them will be based not only on the test results, important as these are, but also on the more extensive data gained as the teacher watches and evaluates the individual children in the variety of classroom situations.

Evaluation must be continuous. Since teaching starts with a philosophy of education, such a philosophy determines the point of view, the nature, the direction of all that is taught. But teaching, once the philosophy of education has been determined, is a whole, unified process. Goals cannot be separated from methods. Materials are interwoven with objectives. And the evaluation of the program is also an essential component of this teaching. Evaluating and appraising the program and the children's progress is integrally related to all of the other parts of the teacher's work.

This concept of continuous evaluation has sometimes been lost. When evaluation is separated from the total teaching program, then appraising becomes merely the categorizing of students. A teacher who sees evaluation as simply giving marks concludes a unit with a test. Then it is easy for him to grade the children according to their test scores. But in this kind of a situation both students and teachers soon come to look at school learnings as hurdles to be overcome and not as accomplishments of intrinsic worth and significance. This kind of appraisal destroys many fine opportunities for effective teaching.

Continuous evaluation and immediate application of what has

been learned can be used in many other ways. For example, it can be used to stimulate students to greater growth toward the desired goals, or it can help identify areas of weakness in the students' knowledges, skills, and understandings. With such an identification of weaknesses, the teacher can take immediate measures to correct the difficulties. Continuous evaluation can clarify and even modify the goals and objectives of the unit or even of the entire program. Finally, this continuous examination of and reflection upon what has been done in teaching can help a teacher determine the effectiveness of his work and allow him to modify his methods to suit the needs of his group.

Using this kind of evaluation in a weather unit can show a teacher if he has set appropriate goals for his class. Can these children understand a concept like "weather front" or do they need more work with simpler ideas? Are these children ready to go on to a study of hygrometers and relative humidity, or must they spend some more time on the function of the barometer and the meaning of its readings? Would it be better for the fast group to move along to some extra work on weather prediction? This day-by-day examination of what has been taught and what has been learned and the consequent modification of procedures in the light of this appraisal is what continuous evaluation means. Just as learning is a continuous modification of behavior, so evaluation, to be effective, must be a continuous examination of children's growth, the program's objectives and goals, the methods which have been employed, the materials which have been presented, and the teacher's own effectiveness. With this kind of appraisal, teachers can take appropriate actions quickly and in whatever directions are necessary.

Evaluation includes self-evaluation. Learning, as this book has continuously pointed out, is a dynamic process. Learners must be actively engaged in the business of learning. They are not passive pitchers into which a teacher pours knowledge. This fact has

important implications for the evaluation program. Since evaluation begins with setting goals, and since self-evaluation is an important part of the evaluation process, then students should have opportunities to participate in the evaluation program from the time it is started. This means that students must be aware of the major goals and must have a part in setting up the sub-goals both for the class as a whole and for himself.

What does this mean in a class? Certainly, the teacher sets the over-all goals for the program. As has been pointed out, he does this even before he has met his children. But once he has set these goals, he can approach his class in a number of ways. One teacher may come into class and say: "We are going to learn about the scientific attitude. Here are the things on which I will mark you. First, do you withhold judgment until you have sufficient evidence for judging? Second, do you think out problems in terms of what you have previously learned? Third, do you plan out several possible hypotheses?" And the teacher could go on listing the goals and setting all the standards and objectives. Students generally react to this kind of teaching with a feeling that the program is being imposed upon them. They are much less likely to accept the purposes of the teacher as their own and their consequent learnings are limited.

But there is another, much more effective way, of setting up the program. The teacher who comes into class and makes a lesson out of the establishment of goals is teaching in such a way as to develop scientific attitudes in his students. He may approach the same problem this way. "One of the things which we are going to work on is developing a scientific attitude towards problems. Now, let's see if we know what that means." Working with the class as a whole, the teacher has the students set up a series of criteria and a set of sub-goals which are the basis for this scientific attitude. For example, the list may include some of the following ideas:

1. To have the students withhold judgment until they have gathered sufficient evidence to support their positions.

2. To have the students think out what they know from their previous studies about the topic under consideration.

3. To learn to develop several hypotheses which can explain what is being studied.

4. To use reference materials so as to find valid and reliable evidence to support a thesis.

From these goals, which the children themselves have helped to establish and which are thus of much greater significance to them, the class can develop a check list for rating themselves with respect to the specific objectives. For each of the sub-goals there can be one or two questions. There might be questions like:

1. Have I thought out what I know from my previous studies about the topic we are studying?

2. Have I thought out several possible hypotheses which can explain what we are studying?

3. What are these hypotheses?

4. Have I looked up references on this topic so that I know what other people have discovered about this problem?

5. What references have I used?

Using such a check list is really a continuation of that phase of the science curriculum which started with the teacher and the students considering the goals of the unit. With such a check list, each student can rate himself periodically in his progress toward the goals. And, with the help of the teacher, he can decide what areas need strengthening or what further attainments he should seek. When the student completes his formal education, he will continually have to judge for himself how well he is doing. The earlier he is involved in self-evaluation, the

better he learns to judge himself both in and out of school situations.

VALIDITY AND RELIABILITY OF EVALUATION TECHNIQUES

There are many methods used for appraising and measuring achievement in science. There are all kinds of tests, all kinds of projects, all kinds of "marking" devices. And this is as it should be. But teachers need to be clear about what such methods can do and what they cannot do. Two key ideas need to be considered in each device which is used for collecting evidence. Each device, to be truly useful, must be valid, and each device must be reliable. Thorough understanding of each of these ideas is basic to sound evaluation generally and consequently to sound evaluation of a science program.

A procedure is valid to the extent that it measures what it purports to measure. Suppose that an important objective of a sixth grade unit is to develop the children's eating habits to the point where they can choose a balanced diet and do eat the proper kinds and amounts of foods. The teacher gives a test on which he lists some foods which the children have already eaten for the day and then asks them to select from a second list those foods which would balance their diets for that day. The children take the test and give the correct answers. Fine. But what does this prove? It certainly does not show that the children had eaten, or would eat, the necessary foods. No, it only shows that they can pick out the necessary items. Such a test would supply only partial data about the students' progress. Information about what they do eat would need to come from other sources—from observation of them in the cafeteria, from diaries which they might keep, from parent conferences. A test, then, is only valid

when it shows how well and to what extent students meet the established objective.

But there are even more serious problems to be considered in relation to the concept of validity. Suppose that one objective of a unit on electricity is to have the children develop the ability to understand the interrelationships of the various parts of an electric motor and, from this understanding, build a simple motor. Then the children are given a test which asks them to identify the various parts of the motor: the armature, the brushes, the field, the commutator, other major parts. Even if they successfully identify all the parts, the teacher does not know if he has reached his objective. Such a test can give a completely inaccurate picture of student performance. Accurately knowing the parts of a motor tells nothing about an understanding of the working relations of these parts. And it certainly tells nothing about whether the student can use his knowledge to construct a simple motor. A valid test of the objective would be one which both required the student to explain the interrelationships of the parts of the electric motor and also required him to build a simple working motor.

There are other factors which detract from the validity of an evaluation device. For example, a test that is constructed to measure knowledge of some specific subject area is an important kind of test and must be used in the evaluation of the science program. But if such a test is worded so that it depends on advanced reading ability or superior vocabulary comprehension, then it cannot be used as a valid measure of knowledge of the subject. Obviously, results from this kind of an examination will not supply accurate information regarding pupil achievement in science subject matter. Then too there are situations in which items are placed on a test which have so little relationship to the stated objectives that they are almost of no use in the evaluation process. Suppose a unit includes as one objective an understand-

ing of the contributions of certain scientists to areas of science. Test questions which ask about date of birth of the scientist or about other personal aspects of his life will give little indication of how well the students understand the contributions of this man to science knowledge. For an evaluation technique to be valid, it must provide accurate evidence of progress toward a specific educational objective.

As for the second condition, it should be noted that a procedure is reliable to the extent that it measures accurately whatever it does measure. In order to achieve such accuracy, it is necessary to use devices that include adequate samplings of a student's knowledge and skills. Again an example can clarify the situation. If a teacher wants to know about how well his students understand the classifications of foods into proteins, carbohydrates, and fats, he cannot simply ask them to match these three words with the words "meat, butter, and bread." From such a question, the teacher would have a far too small sample of what any student knew or did not know. Even if a student got all of this matching question wrong, the teacher would not be justified in saying that he did not know carbohydrates from fats and either of those from proteins. And certainly just because a student answered the question correctly, the teacher could not fairly assume that such a youngster knew anything about the foods and their classifications. This kind of question would provide an insufficient sample from which to generalize about the knowledge of any student.

What can the teacher do? One simple way to solve the problem is to list about fifty foods of the three types and then have the children classify them according to whether they are proteins, carbohydrates, or fats. Of course, the teacher would have to make certain that he used common kinds of foods for his list. He would have to make certain that the words used were not too difficult for the students to read. But by exercising ordinary pre-

cautions a test item could be devised which would have considerably higher reliability than the question of matching meat with protein, butter with fat, and bread with carbohydrate.

OBSERVATION USED FOR EVALUATING

Now come the specific techniques of appraising student work. One of the most useful techniques for evaluating the attainment of many objectives of the science curriculum is teacher observation of pupil behavior. In Chapter III, a unit on "Microbes and Man" was discussed. Two of the major objectives were stated as follows:

To help the children learn simple laboratory techniques with which they can grow and prepare micro-organisms for observation and study.

To help the children learn to use a microscope and a microprojector.

These kinds of objectives can be evaluated most adequately only by observing students' behavior in certain laboratory situations. But observation cannot be random and casual. In the first place, the teacher must know what he is looking for. Take the matter of ability to use a microscope. There are certain accepted procedures for the optimum use of this instrument. Here are a few examples:

1. Handle the instrument with great care. Clean the lenses only with "lens tissue" or with a soft, clean cloth.

2. Never focus the microscope downward toward the slide. Always move the objective downward while the eye is away from the eyepiece and then focus the microscope upward with the eye looking through the microscope.

3. Arrange the mirror for optimum amount of light. Too much light is quite as unsatisfactory as too little light.

4. Prepare materials for observation, using the techniques most appropriate to the things being examined; comparatively large materials (minute crustacia, for example) require either depression slides or bridge arrangements so that they are not crushed; smaller items can simply be covered with a cover slip.

Having determined the desired behaviors, the teacher must prepare a check list or a rating scale based upon these desired actions. Such a list might include:

	Always	*Sometimes*	*Never*
Is careful in handling microscope.			
Cleans lenses properly.			
Focuses instrument properly.			
Prepares slides correctly.			
Arranges mirror for correct amount of light.			

By using such a check list, the teacher can determine the pupil's skill in using a microscope.

In the same way, to check on whether the children have learned the simple laboratory techniques with which they can grow and prepare micro-organisms, direct observation of the students' behavior in this situation will provide the teacher with more accurate evidence for evaluation than will responses by the children to written questions. Obviously answers to written questions can give some evidence and should be used too. But what is wanted from the children is not so much the ability to verbalize about what they should do, as actions which show that they can conduct themselves in the desired manner.

An analysis of many areas of the curriculum reveals objectives which depend mainly upon observation for their evaluation. For example, there are things like assuming responsibility, sharing and communicating with others, practicing proper health habits (covering nose and mouth with a handkerchief when sneezing), developing sound attitudes toward learning, or participating in classroom activities. And all of these areas have significance for the science curriculum. While these areas involve other goals, they pertain to and are all certainly interwoven with the over-all Goal II:

> The elementary science program must help the individual understand the methods, techniques, and attitudes of science so that he may develop a more rational approach to the solution of his current and future problems.

Attaining this goal is an essential part of the science program. *Observation is the most effective way by which to determine how* well it is being achieved.

To sum up, then, observation as an evaluation technique can be effective if the teacher has a clear understanding of the behavior to be assessed. Furthermore, it is incumbent upon the teacher to provide equal opportunities for all the students to respond in the desired manner. This requires a conscious effort on the part of the teacher. Every child must have his chance. Finally, a written record of such observations is not only desirable, it is imperative. How these records are made out—whether they be in anecdotal form, in rating scales, or on check sheets—is not too important. Any of these forms can serve the teacher's purposes. What is essential, however, is that the teacher have a written appraisal of what each child actually has shown himself able to perform in certain areas of behavior according to a set of criteria.

APPRAISING CHILDREN'S PROJECTS

Another very significant way of finding out how well children are meeting the objectives of the science program is the teacher's examination of the material which the children produce. After all, what a child does and what he produces can tell much about the way he meets the objectives of the program. For example, we know that third and fourth graders are collectors. But collections have little worth from a science point of view unless they are organized. One aspect of a scientific attitude is shown by the way in which a person seeks out a theme for his ideas, by the way he organizes his facts and information in a planned classification. A teacher of the third or fourth grade will want the children to begin to develop the ability to conceive of such themes and such frameworks, and to organize their collections and categorize them in the light of these themes. Thus, the teacher examines a collection of rocks and looks to see how the rocks are grouped. Are they organized according to the place where the rocks are found? Are they grouped as igneous, sedimentary, and metamorphic? Are they exhibited to show certain interesting phenomena such as weathering, water erosion, or ice scratches? Or are they just a hodge-podge of pretty stones? Neatness, beauty, novelty are all important, but not for science. What is being evaluated as far as science is concerned is the ability to organize and classify materials in a sensible and reasoned way.

Then there are the experiments which children design and the models which they construct to illustrate applications of scientific principles. An analysis of such materials can reveal much more clearly the extent of a student's attainment of the goal of expanded understandings of science than can any paper and pencil test. A careful study of such materials is one important way of determining growth toward extended vision and richer insight into the meanings of science and the applications of these mean-

ings to appropriate situations. But such a careful study requires that the teacher be sure about the goals he is trying to reach. If this evaluation procedure is to have validity, then the teacher must appraise a project on the basis of the processes used by the student in reaching his conclusion. Extended vision of one's environment, insight into the scientific concepts derived from facts, understanding of how such concepts may be applied to specific problems cannot be measured by the quality of the art work involved in lettering the parts of an exhibit. Rather, it is measured by the clarity of thinking that is shown through the resultant project. It is measured by the extent to which the exhibit explains a science principle through clear and simple examples.

Science reports too need this same kind of evaluation. It is not a matter of how many pictures are included in a report. Rather, it is the appropriateness of the pictures as illustrative of the points being made. It is not the length of the report. Rather, it is the thoughtful organization and clear explanation of the material being presented. And, as far as writing goes, a teacher may very well refuse to accept a report from a child because it is not up to the level of neatness or standards of language skill which he is capable of producing. Misspelled words and poor grammar are not acceptable in science reports any more than they are in English reports. But, returning such a report for rewriting should have no bearing on the science evaluation. In evaluating a science report, the teacher appraises its worth as science—its accuracy of information, its appropriate explanations, its resultant generalizations, its organization. *Science reports must be judged in the light of science objectives.*

The teacher must be certain that the objectives upon which the work will be built and upon which it should eventually be appraised are stated in such forms as to indicate the type of resultant behavior desired. If the objective of a weather unit is to have the children understand the water cycle, then the exhibit or proj-

ect which shows, simply and clearly, how water evaporates and then condenses is much more truly an example of sound science thinking than is an elaborate poster of the various kinds of clouds, beautiful as the art work may be. And a simple home-built model of the workings of a gasoline engine, a model made from cardboard, and paper fasteners, and crayons, is a much more acceptable project than is a plastic, cross-sectional, commercial model of a complex Diesel engine, even though the Diesel engine is put together with great care. What is wanted is a demonstration of how the children are thinking, of how well they understand the scientific principles which they are studying. The home built model shows this. The purchased, plastic model does not. Only as the teacher knows clearly the kind of behavior he eventually expects from his students, and as he helps his students carry out projects which lead to this kind of behavior, can he develop an adequate basis for evaluating the work which his students produce.

ESSAY TESTS

Evaluation is not a new aspect of education by any means. Examinations have been a traditional part of the school ever since there have been schools. The "old-fashioned" examination consisted of a series of essay or discussion questions. In recent years such questions have come under considerable attack. It has been pointed out that many questions of this kind have low reliability and very limited validity and are thus of doubtful worth as evaluation devices. This is true. Essay examinations, as they have been commonly used, often suffer from a narrow and inadequate sampling, from subjectivity of scoring, and from the influence of such extraneous and irrelevant factors as literary skill and handwriting. In addition to these difficulties, there is the problem of the teacher's time. Very often the time and energy expended by teachers in reading and marking papers is so

great as to constitute a serious limitation on the worth of such tests.

Yet there are certain advantages to be gained from essay questions that cannot be achieved by any other form of evaluation. They are especially useful in determining how well a student organizes and presents his thoughts. What is more, such tests can show the ability of the student in analyzing a problem and bringing to bear on it relevant information. Further, such test questions can show the procedures used by a student in arriving at a conclusion. Finally, since no answer which a student gives needs to be completely right or completely wrong, it is possible for a teacher to determine the degree of accuracy of the response to a question. What is needed, then, is a better kind of essay question. Essay questions can be improved so as to include their very marked advantages while, at the same time, their disadvantages are minimized. The following suggestion for constructing and scoring essay questions will prove valuable.

First, the teacher should select questions that are aimed at significant types of understandings. If he gives a question like "What is the composition of the air?" then any answer which he receives, right or wrong, is merely a test of memory. Even if answered correctly, such a question indicates nothing about how well the student understands concepts about air. But take a question like "What effect do large industries have on the air we breathe?" With such a question the student would need to show knowledge about applications of science principles in order to answer it adequately. Of course, he would also have to recall materials that he had learned. But the important thing is that he would have to show ability to use his knowledge for solving the problem posed by the question.

There are other types of essay questions that can indicate significant types of understandings on the part of students.

There might be questions which require the students to make comparisons of one situation with another. A question like "How does the air in a place near the seashore compare with the air at the top of a high mountain?" Or there might be questions dealing with cause and effect relationships. Such a question might be "Many big cities such as Pittsburgh had very dirty air up until a few years ago. Now the air has become quite clean. What caused the air to be dirty and how has it been cleaned?" Furthermore, children can be asked to analyze the components of problems. They can be asked to criticize theories and procedures of scientific significance. They can be asked to evaluate scientific activities in terms of their scientific worth and in terms of their social worth. And they can be asked to illustrate applications of scientific principles. In each of these kinds of essay questions the child has a problem to solve which first requires that he have the necessary information, and then allows him scope in which to show how well he can apply this information in solving the problem.

Second, questions must be worded carefully so that the answers which children give will be limited to the specific objectives which are being measured. Too often essay questions are so vague and ill-defined that they force pupils to guess what it is the teacher desires. If a student happens to guess wrong through no fault of his own, if he interprets a question one way while the teacher wants a different interpretation, then how can such an answer be scored? It is impossible to score an answer reliably under such circumstances. A question like "What effect will atomic energy have on the world?" is much too broad and such a question can be interpreted in far too many ways. Such a question needs to be changed and improved so that it elicits a response which can be used to measure specific objectives. What is more, such a question has to be worded so that the students are clear about the science content to be used in answering the question. Without such clear definition of the

content to be covered, the answers giveo by various children will have no relationships to each other and the answers cannot then be used to guide the children in further learnings. A much more valid appraisal can take place if the question is phrased this way: "Plans are now being made for the peacetime use of atomic energy. Give two examples of how atomie energy could be used io industry. Give two examples of how otomic energy could be used in agriculture." This kind of question requires an answer which is specifically related to a particular objective. There is no uncertainty about what is wanted and no doubt about the cootent to be discussed. When a child answers this kind of question, what he answers shows what he knows about the topic.

Third, the teacher should prepare a scoring guide in advance. By using such a guide as he evaluates the essays, he can have a uniform way of assessing the answers which the children have writteo. One of the chief disadvantages of essay questions has been the inconsistency and unreliability of the scoring methods. Two teachers, giveo the same essay to grade, may come up with extremely divergent grades. Furthermore, a teacher who grades an essay on ooe day and then grades the same essay again a week or two later can often decide on very contradictory scores. To avoid this kind of a situation, if the teacher carefully plans his questions so that he knows what specifie kinds of information he waots in the answers, theo be is more likely to be able to grade the papers reliably. If important ideas are to be included in the answers, these ideas should be given specifie values when the scoring guide is made up. Then, when the paper is marked, such an idea has the same value for everyone. Reliability of the test question under such conditions is markedly improved.

Fourth, every objective that is to be measured by ao essay should be judged separately. Giving one single numerical grade

for an entire essay without some explanation of how the grade was arrived at has little meaning for a student. Grading such diverse things as correct factual information, organization, clarity, and analysis of a problem within the same mark that includes spelling, grammar, and punctuation does not allow the pupil an opportunity to find out in which areas his weaknesses lie so that he can strengthen them. Each value that a teacher gives to an essay needs an explanation. The student should know where his grammar and spelling were deficient. And be also needs to know how well he has dealt with the science content which the question requires. Without such critical analysis, writing the essay has no value in the process of continuous evaluation.

OBJECTIVE TESTS

As concern over the limitations of the essay test developed, teachers turned to the short-answer or objective forms of tests. Today, these short-answer tests are the ones most frequently used in schools. The tests were first introduced to overcome some of the major disadvantages of essay questions as they have been commonly used. For example, essay tests do not allow for an adequate sampling of what the pupils have learned since only a few questions can be included in an examination. An objective test, on the other hand, can include many items. Since each item is short (short to write, and requiring brief and concise answers) a great many of them can be considered in a class period. Furthermore, this kind of question can be scored quickly and objectively. In view of the numbers of pupils who are assigned to a teacher, this can be a real advantage. Scoring a set of objective tests can be done in minutes. A set of essay tests from the same class often takes bours. And, in the case of objective tests, the students themselves can be involved in

scoring the papers. This gives the children opportunities for identifying their own weaknesses, an important teaching technique. In short, there are real advantages to objective tests when they are used properly.

However, there is one major limitation in objective tests. Often objective tests tend to measure bits of superficial and random information rather than broad understandings and more complex abilities. But this limitation, when examined carefully, seems to be more the fault of the teacher who writes the test questions than to be inherent in the nature of the tests themselves. Constructing objective tests is much more than simply writing down a few statements and leaving out a few words for the students to supply. These items can be so easily constructed on a superficial level that teachers sometimes fail to realize the full possibilities of the tests. The questions do not need to be shallow. They can be constructed so that they will test the more complex processes of understanding, reasoning, and judgment.

The two major types of objective test items are usually referred to as "recall" items and "recognition" items. In a recall test, the student is required to provide information, usually in the form of a word or a phrase. A recognition test item, on the other hand, requires that the student select his response from alternatives which are provided for him. There are advantages and disadvantages to each of these types of question.

Generally speaking, there are two kinds of recall items. The simple ones ask direct questions or give specific directions. To these questions or directions, the children respond with a word, or a phrase, or a sentence, for example:

1. What is the source of energy in a flashlight?......................

2. What is the atmospheric pressure at sea level in pounds per square inch? ....

3. Here is a picture of a simple electric motor. Label the parts which are numbered.

The second kind of recall item is the completion item. Completion items require the student to fill in an important word or phrase that has been omitted from a sentence. Examples of such items look like this:

1. A barometer is an instrument for measuring the................ of the air.

2. The two most common gases in the air are.......................... and..........................

Recall tests have certain real advantages. Such items can identify exactly what a pupil knows and what he has not learned in the areas that are considered by the test. After studying the results of such a test, both the teacher and the pupil can know where things stand—what the pupil has learned, and what he still must learn. But there is one major disadvantage to such a test. The scoring cannot always be completely objective. There is always the possibility that the pupil will answer with a word or a phrase that is different from the one which the teacher expected. These answers may be quite as true as those which the teacher wanted. Take the statement:

The two most common gases in the air are..........................
and..........................

If a child were to answer "invisible" and "important," he certainly would have a correct answer. But how should a teacher mark such an answer since what he wanted was simply "oxygen" and "nitrogen?" Truly, this kind of item cannot be used indiscriminately.

Recognition tests also have several forms. The most widely used type of recognition item is the alternative response. Commonly, the alternative response is *true* or *false*. The student is given a statement. He must decide if it is true or if it is false and mark his answer accordingly. Here are two examples of such items:

	True	*False*
1. It is the oxygen in the air which supports combustion.	....	....
2. An anemometer measures the direction of the wind.	....	....

The obvious advantages of using this type of test are the relative ease with which such items can be constructed and the objectivity with which such a test can be scored. But such tests have serious limitations and these disadvantages very much outweigh the merits. In the first place, these true-false questions encourage guessing. Then too, such questions often are worded ambiguously. Or they may have very obvious answers and thus test nothing. Finally, they have little value for the student. He cannot identify his areas of weakness from his answers. And teachers must remember that a test, if it is worthy of administering, must serve the student in identifying such areas. Because of these marked shortcomings, true-false items should be used with great caution. It is a good rule to use this kind of item only in those situations where the other test forms are not applicable.

A second kind of recognition item is the multiple-choice item. Here, the student is given an introductory statement or stem and several alternative answers from which he must choose the one that is most appropriate. Such items might be worded as follows:

1. The richest source of vitamin C in the foods listed below is:
a) raisins b) grapefruit c) pears d) cherries.

2. We get the most iron from a normal serving of:
a) fish b) veal c) liver d) ham.

3. We get the highest caloric value from one ounce of:
a) lean beef b) banana c) white bread d) butter.

The multiple choice item has real merit. It is considered the most valuable and most flexible for testing various kinds of mental processes. This type of item lends itself to determining reasoning ability, to showing understanding of processes, to indicating soundness of judgment. Furthermore, the possibility of guessing the correct answer is reduced almost to a minimum when at least four plausible alternatives are given. But these multiple choice items are more difficult to construct than are other types of test items. The important points to watch are first, that the items measure something more than rote memory, and second, that all the alternative answers are plausible while only one of them is correct.

Finally, there are the matching-item tests. Typically, such a test consists of two columns of items which are to be associated upon some directed basis. There are many possible variations of these matching tests, but, in its simplest form, the number of responses is exactly the same as the number of items. These tests can be made more complex in a variety of ways. Sometimes more responses are provided than are required. Sometimes three or more sets of items are given and the student must match the three or four columns with one another to get the required answers. Generally, however, for elementary school programs, only the simpler tests need be constructed. Here is an example of this kind of question:

Directions: In the space next to each word in Column I place the letter of the best answer from Column II.

Column I	Column II
—1. Force	A. The rate of doing work.
—2. Energy	B. A push or pull.
—3. Power	C. Capacity for doing work.
—4. Speed	D. Rate of change of position.

These matching exercises are particularly well suited for measuring specific aspects of subject matter areas. They can show whether or not a student understands basic terms, whether he knows definitions, whether he can associate events with persons, whether he can connect science principles with examples of them, whether he can identify tools and their uses. But the difficulties are there too. Such tests often measure only rote memory and the science program must be much more than a memory program. And these matching questions are difficult to construct. Often they need more time than they are worth.

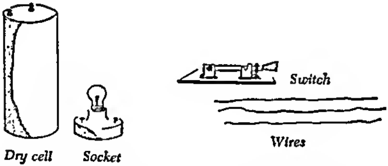
Looked at carefully, the use of objective tests takes on a different perspective. Such tests can be useful. They certainly are easy to correct. And they do give objective measures of certain kinds of achievement. But they have flaws too. *Good test items are difficult to construct. And many items do not measure what they are supposed to. In brief then, teachers undoubtedly should use objective tests. But they should construct the test items with the utmost care and they always should remember the limitations of such tests.*

TESTS OF APPLICATION

The test of application is another useful device. On the one hand, it is a paper and pencil test. But it attempts to measure the pupil's comprehension of basic principles through giving

him an opportunity to show how these principles are applied to the solution of a particular problem. In the unit on electric circuits which was developed for the third grade (Chapter IV), one of the things which Miss Edwards wanted the children to learn was how an electric circuit could be made. In order to determine whether this information had been learned, she might have had each child wire a simple circuit. She could give each child a dry cell, a few pieces of wire, a bulb and socket, a switch, and any other items that he might need, and then have him get the bulb to light. But such a procedure would take a considerable amount of time. There is, however, another way to evaluate this sort of skill. A test like the following might be given.

Here are pictures of the things we need to make a bulb light. Using all the things that are drawn, show how you would connect the wires so that the bulb will light.



From this test the teacher would not find out how well the children could use pliers or screw drivers; but it would show which of the children had a generally accurate idea of how a switch fits into a circuit and of how a completed circuit would look. This kind of test, while not as comprehensive as an actual performance test, is nevertheless a useful substitute, which will accomplish nearly the same result.

STANDARDIZED TESTS IN ELEMENTARY SCIENCE

As the science curriculum expands in the elementary school, new standardized tests will become available to supplement the teacher-made tests. These tests serve the teacher as a further means of measuring the attainment of objectives. There are several advantages which can be gained from the use of such tests. In the first place, because they are carefully prepared by experts in the field of testing, they generally have a high reliability. Furthermore, such tests usually include norms which indicate the range of scores of students of each grade. These norms make it possible for a teacher to determine how the development of his students compares with that of students in other schools. Sometimes standardized tests can also be useful in diagnosing individual progress within the class by identifying areas of strength and weakness. Finally, a standardized test can be used at the beginning of a school year to determine the achievement level of the class. With the information furnished by such a test, a teacher is better able to judge what content should be developed for his class and where he should place his emphasis.

Over the past several decades, attempts have been made to build standardized tests for all schools programs in various areas of the curriculum. Thus, for the elementary school there are reading tests, arithmetic tests, social studies tests, and many others. But, except as these tests have been devised to measure skills (the ability to read for speed, the ability to comprehend what has been read, the ability to perform fundamental operations in arithmetic), such standardized tests can measure only the amount of information an individual has acquired. Therefore, standardized science tests are supposed to measure the amount of science information which the children have learned. But this is

difficult to do on a nationwide basis since there is no general agreement with regard to the content of the elementary science curriculum. In the present circumstances of limited agreement on curricular organization and content, every standardized science test suffers from a lack of validity. These tests should not be used unless the items in them coincide with the instructional objectives. Thus, standardized tests in elementary science bave questionable worth and, even as the elementary science program develops more uniformity around the nation, they sbould still be used with the necessary reservations.

Summary

The most important thing to remember about all evaluation is that it must be used widely and fully. The many kinds of evaluation—observation of student behavior, appraisal of student projects, and the variety of paper and pencil tests—yield a wide range of information. But unless sufficient use is made of the results of such observations, appraisals, and measurements, they become a waste of time both for teachers and for students. Such evaluative techniques have three basic uses. In the first place, they can provide the teacher with the means for assessing the growth of individual students. Secondly, such devices can help each student know his strengths and weaknesses. This phase of evaluation is most important and bas been most neglected. Finally, through the use of these devices and techniques, a teacher can learn how well he is meeting his objectives.

Clearly, there is no simple, single device for evaluating children's growth in science. All kinds of instruments are needed in order to appraise satisfactorily the work of students. Here are several suggestions which will be of help in determining an effective program of evaluation through observation:

1. Be quite sure of what you are looking for. Your observa-

tions must be directly related to the objectives of your program.

2. Establish criteria for evaluating the observed work of the children before you try to judge them.

3. Record your observation of what the child does, as well as your appraisal of what he has done.

4. Keep your observational records in writing just as you would any other kind of evaluation. Do not trust such observations to memory because you will forget what you have seen.

But written tests are much more commonly used and much more widely accepted measures of achievement in schools. So here are several suggestions for making such written tests more effective.

1. Every evaluative instrument must be directly related to the objectives and sub-objectives which it is going to measure.

2. Individual parts of the test must correspond to the sub-objectives which they are going to measure. And there must be an adequate sampling of questions and an appropriate emphasis on each objective.

3. The directions for the test must be clear and complete and each student must know exactly what is expected of him.

4. The reading level of the test should be kept low so that the students who take the test will be able to understand what they read, even though they may not know the answer to the questions.

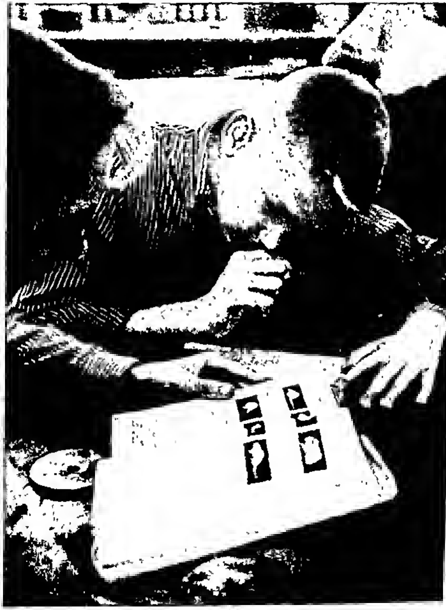
5. All of the items of a particular type should be grouped together in the test. This arrangement will not only make scoring easier but will also allow the student to take advantage of the mind-set which comes as one works with a particular kind of question.

6. Construction of the test is the most important single factor in a testing program. The pitfalls to be avoided are:

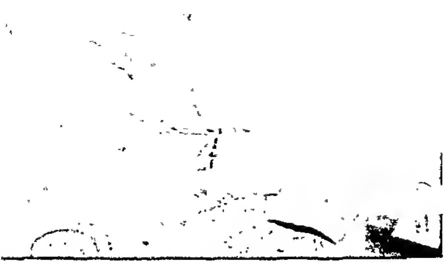
"trick" questions, ambiguous questions, obvious items, cues that will provide answers for other questions.

Remember that the teacher is the ultimate evaluator. A test of any kind can give information about the student. But only a teacher can look at this information, weigh it, add and subtract related data, and come up with an appraisal of where a student is in relation to his potential, and how he can be helped towards his optimum growth.

ACADEMICALLY ABLE CHILDREN
STUDY DIET AND NUTRITION



What does the book have to say about mice?



Now the specimen is ready to be weighed.

Weighing requires accuracy.

The teacher helps make the formula.

The prize specimen is photographed.

"See how well our mouse is doing."

XII BUILDING A PROGRAM FOR GIFTED CHILDREN

EVERY child deserves the very best education which he is capable of receiving. One of the real problems of the school has been that teachers have not been able to bring out the very best in the various students who have been members of their classes. This is by no means a new problem. Teachers have been struggling with it for centuries. But within the past few years Americans have become very concerned about the fact (and it is a fact) that many of the more able children have not been challenged to work at the levels of which they are capable. It is particularly true that those children who are academically oriented and who learn quickly and with comparative ease have often been the most neglected students in the schools. The reasoning by many teachers has gone something like this: "We must give most of our attention to the average students. They make up the largest portion of the student group. The capable children will learn no matter what we do. So we must concentrate the time we have on the average (whatever that may

mean] students." This method has brought about a leveling process. It has tended to keep the more able children at the level of the average group while it has striven, often unsuccessfully, to raise the less able to this same average level.

The recent cry bas been that this concentration of time on the "average" group is not only unfair to the able students, but is also a waste of human resources, the most valuable of our national resources. The attempt to solve this problem is not new; over the past fifty or more years many devices have been tried in order to serve the varied needs of students. High schools have had departmentalized programs and separate "learning tracks" for a long time. And "homogeneous groupings" have been employed in many elementary schools where there are two or more classes in the same grade. Other schools have tried other plans. In some cases there have been attempts to build individualized programs for each child. In other places the programs have been geared to one group or another while deliberately ignoring the needs of those who are not able to profit from the particular course being offered.

But regardless of which position a community or school has taken, there have always been a few teachers who have found ways of reaching most of their students. When the work of these teachers is examined, tbe common elements that can be found are that, on the one hand, they have had a broad knowledge of the material which they teach, and, on the other hand, they have had a very personal understanding and appreciation of the individual children with whom they work. Apparently this combination of factors has been the determinant of success in challenging each child to attain his optimum development. It should be made clear that the teacher does not have to be an authority in each of the subjects he teaches. Rather, what he needs is an understanding of the basic concepts in the area of study and an ability to ask those questions which will push his

students on to finding some answers. Further, what the teacher needs is a set of resources (people, books, other materials) which can help the students explore the questions.

Obviously, if all children are to work, each at his level of ability, then teachers must develop certain special techniques for working with the more able children so that they can have the opportunities and the challenges which they deserve. Here then are some suggestions for working with such children whether they are in a class with children of less ability or whether they have been sorted out by some technique and grouped together in a special class.

IDENTIFYING ABLE CHILDREN

There is no general agreement on a definition of "gifted" children. We know that they are likely to score well on intelligence tests. We know that they are likely to function effectively in classroom situations. We know that they are usually able to work effectively and reliably by themselves. They persevere at tasks which they set for themselves. They read well. They read assiduously. They see relationships among the various ideas which they meet. They can generalize and develop concepts from items of observation. They can deal with abstractions.

The only trouble with this kind of operational definition of "giftedness" is that many children who are not "gifted" do these things and some "gifted" children do not do all of them. However, for purposes of identification, it would seem wise to consider those children who indicate the following characteristics as being capable of doing more extensive and intensive academic work:

Intelligence quotient—120 or above

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Intelligence quotient—120 or above

Reading score on a standardized test—two grades above regular grade

Adjustment to both his peers and his teachers which makes him an academic leader in his group

Ability to work effectively on his own as indicated by his power to concentrate on his work in varied situations

Perseverance in carrying out his tasks

These criteria may exclude some children who are really "gifted" and include some children who cannot be so classified. However, a group established on this basis will generally consist of those children who can profit from special and additional work in science or in other areas. Therefore, in this book, these children shall be called "academically able" or just "able" children.

SCIENCE CURRICULA FOR ABLE CHILDREN

There are two courses of action which can be taken with these able children. On the one hand, when they are grouped together in a special class or in a sub-group of a regular class, they can be given advanced work and accelerated through the elementary school and high school programs. In that kind of situation, third graders can work on fifth grade material and sixth graders can work on ninth grade material and then, when these children reach high school, they can complete the high school course in one or two years. And there is every reason to believe that many such children can do this. But there are, among others, two major disadvantages to such a procedure. First, if children are to accelerate, then once such a group is established other children cannot come into it. They would not have the necessary background to keep up with the original group. And, secondly, many people contend that even though it is possible for a ninth or

tenth grader to complete the academic work that is normally carried on through the twelfth grade, most young people who are only fourteen or fifteen years old are not emotionally, or physically, or psychologically ready to go off to college, or at least to the colleges as they exist in America today.

But there is another course of action which can be followed with able children. The curriculum can be enriched either by expanding the usual units of work to include special activities for these able children or by adding special units of work for such children from areas that are not normally included in the public school science program. Either of these proposals is fine *if* it is carried out in an organized and regular way. The difficulty has been that generally the enrichment program in each classroom has been left to the discretion of the teacher, while in those cases where there have been special classes for the more able children, there has been no general agreement among the teachers of those classes as to what kinds of enrichment units should be added to the program. In other words, the enrichment program usually has been haphazard and often even weak.

EXPANDING THE SCIENCE PROGRAM FOR THE ABLE CHILD

The able children should complete the curriculum established for all of the children. But these able children can comprehend the material much more rapidly than the other children and also they can see relationships beyond those that most of the average children can. This means that if the able children are to work in heterogeneous groups, then there is a need to find ways of expanding the science units.

It has been shown that the science units must grow out of the major science generalizations which were outlined on page

30 in Chapter III. These seven generalizations provide the foundation upon which all of the science work is built. A typical science curriculum for the primary grades might include many of the following units, based on the seven generalizations:

1. *There are many kinds of living things and they are interdependent.*
Animals in our world
Plants in our world

2. *There are many forms of energy which can be changed from one to another, but most of the energy which men use is derived from the sun.*
Heat and temperature
Magnets
Energy and energy sources

3. *The earth is a small part of a vast universe containing other planets, stars, and astral bodies.*
The earth and the sun
The sun and its planets

4. *The earth's story, its history and current condition, can be read from its rocks, soils, and waters.*
Different kinds of rocks and how they came to be
Different kinds of soil and how they came to be
The air and the atmosphere

5. *Living things are dependent upon the earth and its atmosphere and the sun for their food, their shelter, and their very lives.*
Weather and climate
Living and non-living things

6. *Men have learned how to use natural forces, both chemical and physical, to make their work easier.*
Fire and fire prevention
Simple machines
Sound and music

7. Men must use their knowledge of science to keep themselves healthy and to improve society.
Foods we should eat
Preventing the spread of disease

Of course such units would be built around a variety of basic concepts which would be developed with the children. For example, some of the concepts which might be appropriate to a unit on "Animals in Our World" might be:

No matter where an animal lives, he needs water, food, and shelter.

Animals adapt themselves to the kinds of environments in which they live.

Animals have different ways of protecting themselves.

Animals have different ways of obtaining their food.

All of the children should be able to understand and use these concepts. But in addition to learning this general information, the more academically able children can do two things. First, they can find information about some of the more unusual animals and their habits and habitats. Second, they can work on more complex and abstract aspects of these concepts. For example, they can carry the concept of adaptation to environment to a more advanced stage and make a study of the ecology of the communities. They may investigate the kinds of animals and plants that inhabit the same areas and find out some of the reasons why these living things exist together in a given environment. Another deeper study could develop the fact that many of the same kinds of plants and animals inhabit places on the earth's surface which are seemingly inaccessible to each other. For example, there are the animals and plants which are common to the temperate zones all around the earth. Tiger swallowtails are found in a band around the globe. In

the same way, some grasses follow the temperate zones around the earth. And there are many other such phenomena to be investigated. In planning each unit, the teacher should include in the over-all plans the areas of enrichment which he will use with his able students.

Similarly, these generalizations lend themselves to the development of units for the intermediate and upper grades. A unit on weather and climate can have special work for the more able children on the preparation of weather maps, adiabatic systems, and air mass analysis. These able children also can explore the areas of weather prediction and weather control. A unit on electricity can include some simple introduction to electronics such as the use of vacuum tube circuits for controls, amplification, and computers. A unit on the history of the earth can provide some of these children with opportunities to consider some of the facets of glaciology such as the ages of glaciers, the movements of glaciers, the relationships among ice, water, and climate on a world-wide scale, and theories concerning the causes of ice ages. Each of the regular units then must also provide extra material for the able children and *these materials must be planned for in advance of the unit.*

DEVELOPING SCIENCE UNITS FOR ABLE CHILDREN

Since the special classes of able children can and will complete quite rapidly the regular curriculum established for all children, they also should have the opportunities for enriched materials that are planned for the able ones in the heterogeneously grouped classes. But such a special class should have still another aspect to its program. There should be specially developed units of work which would not normally be included in the regular program. These additional units can come from areas of study

that the children will not meet later in their public school programs. This means that even though some sixth grade children probably could understand the materials normally included in the study of the biology of human reproduction—materials which they would normally meet at the ninth or tenth grade level, it is not wise to include them at the sixth grade level. Rather, it would be more advantageous to develop units based on a topic such as the incubation of chicks or on some other phase of embryology. Again, rather than study some phase of physics which will appear later in the students' high school careers, it would be better to develop an area like the nature and use of the telescope. In such a unit, the children could be given opportunities to build and work with telescopes. Not very much is done with the area of laboratory astronomy in most of the regular elementary science curricula. The more capable children certainly can be encouraged to explore this area.

Here, grouped according to the major generalizations of science, is a list of a few of the special science units which might be carried on with a class of able children:

1. *There are many kinds of living things and they are interdependent.*
Developing various systems for classifying plants and animals
Studying some of the exotic plants
Studying unusual animals and their habits and habitats
Learning about the wide variety of micro-organisms

2. *There are many forms of energy . . .*
Developing simple experiences with solar energy, such as making a solar stove
Finding out about unusual transformations of energy, such as photoelectric and piezoelectric transformations
Finding out the ways in which earlier men used energy to do their work
Finding ways of measuring energy

3. *The earth is a small part of a vast universe . . .*
Varied theories about the origin of the earth and the universe
The nature of astral bodies beyond the Milky Way
Learning about the tools which men use in order to find out about the universe, including a careful study of the telescope
Bringing information from various sciences together in order to find out about the universe

4. *The earth's story, its history, and current condition can be read . . .*
The story of IGY
The nature of the atmosphere
The oceans and their resources
Man-made satellites and what they can do for us
Measurements through the ages

5. *Living things are dependent upon the earth and its atmosphere . . .*
Ecology of very small communities
Formation of different kinds of soils and how they effect plant growth

6. *Men have learned how to use natural forces . . .*
Measuring the efficiency of machines
Using light to do our work through photography
Science principles to be found in important inventions

7. *Men must use their knowledge of science to keep themselves healthy . . .*
The biographies of certain important men of science (Pasteur, Lister, Leeuwenhoek, etc.)
Science and food supply
Science and water supply

Certainly, all of the possibilities have not been stated. But these examples can illustrate the kind of enriched curriculum that such able students can follow in addition to the work that is done by all of the children in a given grade.

PLANNING SCIENCE UNITS FOR THE ACADEMICALLY ABLE

Each unit for the academically able children needs to be worked out in the same way that the units are planned for regular groups. But the resources for these more able students must be on a more mature level. The reading level can be higher; for example, current periodicals can be used for references. Furthermore with this kind of class, teachers can feel quite free to call on the science personnel of the community to help the children with both their individual projects and with the total class program. Organizing special science seminars in which various citizens with science jobs come to school and talk with the children about their work is one way of enriching the science program for able children. This kind of program has received considerable support from industry. Top science personnel have given much of their time to such projects and, surprisingly enough, they have found most of their satisfaction from dealing with able elementary school children. These children seem to profit more than others from the discussions of specialists.

The objectives for the units can be more complex and more abstract. For example, the unit about IGY might include some of the following:

Objectives:

1. To find out how men of science work together to gather information about the earth
2. To learn about the various areas of science which IGY studies and to understand some of the work involved in each of these areas
   a. Oceanography
   b. Glaciology
   c. Aurora studies
   d. Terrestrial magnetism

e. Cartography and the size and shape of the earth
3. To learn about some of the instruments and machines which the IGY scientists use in their work

There certainly will be other objectives for such a unit, and though they will be established according to the principles already stated in this book they will tend to be more difficult than those established for the regular curriculum. In like manner, the activities for such a unit can be more complex and more advanced. For example, the children can build telescopes and participate in moon-watch or other observation groups; those who live near the oceans can make salinity studies; in inland areas, the studies can be made of the fresh water lakes and the streams. School-wide and even community-wide museum exhibits of the work done by IGY, including models of satellites, of arctic and antarctic IGY stations, of atmosphere-study balloons, and of the many other instruments and pieces of equipment of the scientists of IGY, can be built and manned by the children in these able groups.

There are other areas to be studied also. For example, many communities have amateur radio facilities and the children can assist the radio "hams" and learn some of the technical and international aspects of amateur communication. The study of glaciers also can be very interesting and profitable. So can a study of the local water supply from the point of view of water table problems. Working with able children requires that the teacher look for some of the more unusual and more complex aspects of a science topic.

There are a few warnings about the development of such units for able children. In the first place, these children, though they are much more adept in the use of language, still need to have many concrete experiences. They too need to build models. They too need to try things out and to learn through a variety

of experiences and experiments. Secondly, these are children who can and should learn to work independently. They should have many individual projects and many opportunities for individual explorations and experiments. Finally, these are children who can and should be kept to high standards. They must not be allowed to make careless errors in either mathematics or writing, and they must be required to state their information precisely. The quality of their science work should reflect their ability.

EVALUATING THE WORK OF ABLE CHILDREN

Evaluating the growth of academically able children is really the same as evaluating the growth of any children and so the generalizations which appear in Chapter XI also hold for these children. But in using these techniques of evaluation, teachers of able children should pay particular attention to certain kinds of growth. Here are a few questions which are particularly appropriate in the evaluation of academically able children:

1. Does the child do a thorough job even though he is working independently?
2. Is the child learning more than mere verbalizations? Can he *do* science as well as *talk* science?
3. Is the child learning how to find problems for himself and establish goals for solving his problems?
4. Is the child learning to use the instruments of science accurately?

The academically able child is likely to become a technically skilled adult. He can and should become an intellectual leader. Thus, he must be taught to work independently, accurately,

and thoughtfully. Teachers, in measuring his growth, must be certain that these aspects of his growth are receiving thorough nurturing.

Summary

Since every child is entitled to be educated to the best of his ability, it is quite clear that when planning the science program for the elementary school, specific plans must be made which give consideration to the needs of the able child. Furthermore, these able children must receive their deserved attention when the science program is carried out. They should have more advanced and complex work based on their abilities. Of course, they should be held to the standards set for the general student body, but beyond that, they should be expected to delve deeper into subject matter and achieve greater skills in working in science.

True giftedness in individuals is rare indeed. There is only one Newton in a thousand years and only one Einstein in billions of people. But ability to work with abstractions is not an absolute; it is not an "either-or" situation. Rather, all people have some ability in this area and some people have quite a bit of this ability. The ability to deal with abstractions is an important resource both for the individuals who have it and for the nation as a whole. Schools and teachers must do all in their power to encourage and nurture these resources.

THERE IS WORK FOR ALL CHILDREN IN SCIENCE

Growing crystals by evaporation is this boy's project.

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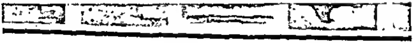
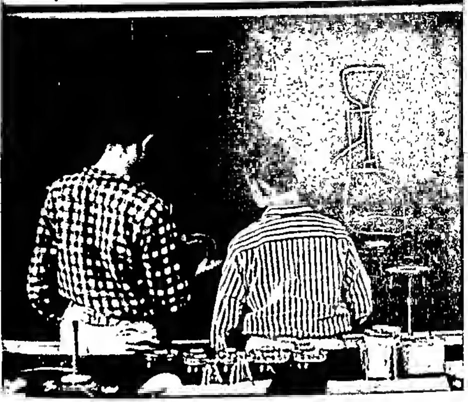
Growing crystals by evaporation is this boy's project.

1. *First the equipment is assembled.*

2. *"Let me show you how it should be."*



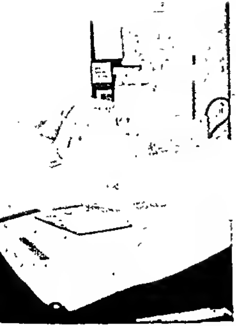


3. *"No, that's not right. It should be this way."*

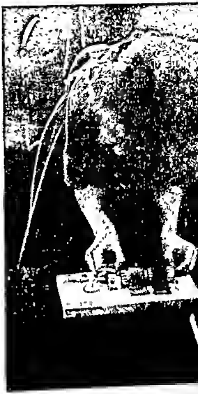
4. *"We'll leave it on the board for tomorrow."*

In a busy classroom many projects go on at once.

It's hard but rewarding to make your own equipment.



Preparing a chart of the elements is a valuable experience.



She made the bulb light.

Sometimes it takes four hands to make it work.

It is often helpful to discuss a project with someone else.

His wet cell attracts attention

XIII TOOLS FOR TEACHING ELEMENTARY SCIENCE

THAT there is reason to teach science in the elementary school, there can be no doubt. That there are ways to teach this science so that all teachers can do creative work in the area is also clear. But elementary science is truly "general science" in the real meaning of the term. Such foundational information along with the techniques for working with science materials, the attitudes toward the world, the ways of searching out and solving problems that grow from all the science disciplines must become an integral part of the basic general education of every American citizen.

To teach science, teachers need clear, specific objectives; they need sound teaching techniques; they need methods of evaluating what they have taught. But they also need tools. The tools of teaching are those materials with which the teacher brings his program to life. They are the materials with which he builds a vital, individualized, and meaningful program. He needs:

(1) special science equipment which is simple yet adequate; (2) a basic classroom library and bibliography of additional books; (3) a list of films and filmstrips; (4) a resource file of materials and of field trips; (5) a knowledge of where to turn for suggestions for new or additional activities. In short, the teacher must have a reservoir upon which he can draw as he carries out his program. The following list of materials provides such a source.

SPECIAL SCIENCE EQUIPMENT

Elementary school science equipment needs to be simple. But it needs to be provided for every classroom. As has been pointed out over and over again, elementary school science is an active not a passive program. This means that there must be an abundance of equipment available in the school. The necessary science equipment can be divided into two groups. On the one hand, each teacher needs certain basic materials in his classroom which he can make available to his pupils at any time. A few simple hand tools such as screw drivers, hammers, pliers, an assortment of bottles, jars, and dishes, a few dry cells and some wire are good examples of these kinds of materials. On the other hand, there are the more expensive and more permanent pieces of equipment such as microscopes and microprojectors, galvanometers and demonstration generators, and model steam engines which should be available through a school-wide science supply whenever a teacher needs them. It is desirable that each school have a science room where the teacher can take his group to work on special science projects and where the science equipment can be stored. Lacking this, however, the science center can be a supply depot and storage room. Such a supply depot can be part of the school library or the audio-visual center, or it can be located elsewhere in the building. The center should contain at least one locked closet where valuable equipment (for

example, microscopes) or materials which should not be used without teacher supervision (for example, acids) can be stored. The supervision of the room can be the responsibility of the science specialist, if the school has one, or the librarian, or a classroom teacher, or a school clerk, or a committee of older children. Materials can be easily and safely moved from place to place in the school even by children if a cart such as is found in the cafeteria or in a super-market is used.

The equipment list does not include machines for projecting films, filmstrips or slides. Such equipment is important to science teaching and should be obtained from the audio-visual center. Projects which require major construction or large amounts of art work should use the shop and art facilities. The list of materials and supplies which follows has been selected because it offers a very wide variety of activities with comparatively small expense. The chemicals, for example, can serve many purposes, from flame tests to show the children one method of identifying elements, to ingredients for simple fire extinguishers. The variety of electrical equipment can be useful at many grade levels, as can the steam engine or the microprojector. Amounts and quantities of materials are not given since these will vary from class to class and from school to school depending on size of budget, numbers of children, and specific needs. However, the teacher should remember that an active program requires sufficient supplies so that all of the children may be involved in the program. The asterisks in the equipment list indicate materials which should be in each classroom.

Aneroid barometers
Thermometers
  *Outdoor thermometers
  *Room thermometers
  Clinical thermometers
  Chemical thermometers,
    Fahrenheit and centigrade
  Cooking thermometers
  Air thermometers
Hydrometers, heavy and light liquid
Graduated cylinders, assorted sizes, both English and metric markings

Scales
- Two-pan balances
- Spring balances
- Kitchen scales
- Bathroom scales
- Weights, both metric and avoirdupois

Air pumps, compression and vacuum

Battery jars

Bell jars

Anatomic models
- Human torso
- Human eye
- Human skeleton

Color wheels

Prisms

Lenses, assorted, including
- Concave lenses
- Convex lenses
- Old eyeglasses

*Magnifying glasses

Mirrors
- *Plane mirrors
- Curved mirrors

Microscopes
- Slides
- Cover slips
- Lens paper

Microprojectors

Tuning forks, assorted frequencies

Wires of assorted thicknesses and lengths (for sound)

Dry cells, assorted, including
- Storage batteries
- *1.5 volt cells
- *Flashlight batteries
- (Be sure to keep some dead cells for children to break open and examine.)

Wire, assorted, including
- *Bell wire
- Heavy insulated wire
- Zip cord (used on household appliances)

Switches, assorted, including
- *Knife switches, assorted including: single pole, single throw; single pole, double throw; double pole, single throw; double pole, double throw
- Toggle switches
- Push button switches
- Pull chain switches (on lamp sockets)
- Twist switches (on lamp sockets)

Sockets, assorted, including
- *Miniature sockets (for flashlight bulbs)
- Standard base sockets
- Fluorescent fixtures

Bulbs, assorted, including
- *Flashlight bulbs (for use with 1, 2, and 3 cells)
- Standard base, assorted wattages (some clear glass)
- Fluorescent bulbs

Fuses, assorted

Electric wall receptacles

Electric plugs

Friction tape

Extension cords

Soldering irons

Solder

Galvanometers

Rheostats

Spark coils

Telegraph sets

Telephones

Doorbells
Magneto or generator model
Radio equipment
  Antenna coil (standard broadcast band)
  Antenna wire
  Variable condensers (365 mmf)
  Crystals and ticklers
  Fahnestock clips
  Head phones
  Old radio parts, *including* tubes, speakers
Magnets
  *Bar magnets
  *Horseshoe magnets
  Alnico magnets
  Floating magnets
  Electromagnets
Large nails (for making magnets)
Iron filings
Compasses
  *Magnetic compasses
  Free needle compasses
St. Louis Motor
Electrolysis apparatus
Model steam engines
Model machines (which can be hitched up to steam engines)
Pump models, lift and force
Pulleys, assorted, including
  *Single pulleys
  Double, triple, and quadruple pulleys
  Tandem pulleys
Gasoline engines
  Demonstration model gasoline engines
  Old lawn mower engines
  Model airplane engines
Radiometers
Thermostats
  Bi-metallic thermostats
  Thermostatic switches
Photography equipment
  Pin-hole cameras
  Lens cameras
  Daylight paper
  Blueprint paper
  Prepared developers and fixatives
  Trays
Rock and mineral collections
Shell collections
Seed collections
Insect collections, including cocoons and egg cases
Clocks (for the children to take apart and examine)
  Pendulum clocks
  Spring clocks
  Striking clocks and alarm clocks
  Electric clocks
Old household appliances
  Irons
  Toasters
  Mixers
  Fans
  Heaters
  Vacuum cleaners
Soil testing kit
Test tubes, assorted sizes, both pyrex and soft glass
Test tube brushes
Test tube racks
Test tube holders
Flasks, assorted sizes and shapes
Beakers, assorted sizes
Evaporating dishes
Filter paper

*Pans
*Jars
*Glasses
*Spoons
Tongs
Wire gauze
Iron extension rings
Ring stands
*Asbestos pads
Bunsen burners (Use burners with attached bottle gas if piped gas is not available in school.)
*Electric hot plates
Clamps, assorted
Pinch cocks
Thistle tubes
Funnels
Rubber stoppers, one- and two-hole in assorted sizes
Corks, assorted
Rubber hosing, assorted sizes
Glass tubing
  Assorted sizes, including thermometer tubing; barometer tubing, large bore
  T Tubes
  Y Tubes
Pneumatic troughs
Thin rubber sheeting
Mortars and pestles
Crucibles
Glass squares
Petri dishes
Blow pipes
*Medicine droppers
Plaster of Paris
Cement
*Modeling clay
Hand tools
  *Screw drivers
  *Hammers
  *Pliers
  Chisels
  *Saws
  Mallets
  Tin snips
  *Files
*Nails and screws, assorted
*Colored paper and cellophane
*Candles
*Straws
*Brushes, both water color and larger paint brushes
*Water colors
*Colored inks
Food dyes
*Scissors
*Knives, particularly pen knives
*Pencils and pens
*Colored chalks and crayons
*Wood splints (Tongue depressors and swab sticks can be used.)
*Adhesive tape, both cellophane and cloth
*Aluminum foil
*Pliofilm
*Pins
*Paper clips and fasteners
*Thumb tacks
*Rubber bands
*Labels
*Thread—strong sewing thread
*Needles, both darning and metal knitting needles
*String
*Sealing wax
*Paste
*Glue
*Protractors
*Drawing compasses

*Rulers, twelve- or eighteen-inch
*Yardsticks
*Meter sticks
*Matches
*Balloons
*Marbles
*Flashlight
Dissecting pans
Dissecting kits
Deflagration spoons
Static electricity equipment, including
Rubber rods
Glass rods
Silk
Fur
Wool
Pith balls
Electrostatic toys
Electroscopes
*Absorbent cotton
*Cardboard milk containers, half-pint and quart size
*Tin cans, assorted sizes
*Wooden boxes, assorted sizes
*Globe
Geodetic survey and three-dimensional maps (especially of local area)
Wire netting
*Aquaria
*Terraria
Ant houses
*First aid kits
*Blankets
Sand buckets
*Fire extinguishers
*Flower pots
*Watering cans
Hydroponic materials for plants
Spades
*Trowels
Soil (It's hard to come by when the ground is frozen.)
Gravel
Star charts
Models of the solar system
*Rubber balls, various sizes
Pieces of wood
Pieces of metal
Enamel pans
Egg beater
Sauce pans
Kettles
Pinwheels
Strainers
*Rubber gloves
*Can openers
Salt
Cane sugar
Grape sugar
Baking soda (sodium bicarbonate)
Baking powder
Rice, white and brown
Lima beans
Kidney beans
Corn starch
Flour
Gum arabic
Paraffin
Steel wool
Vaseline
Corn oil
Sand
Charcoal
Lamp black
Litmus paper
Kerosene
Vinegar
Turpentine
Gasoline

Machine oil
Chemicals
- Alcohol
- Acetic acid
- Benedict's solution
- Benzine
- Boric acid
- Bromthymol blue
- Carbon disulphide
- Carbon tetrachloride
- Ferric chloride
- Formaldehyde
- Glycerin
- Hydrogen peroxide
- Iodine solution
- Lead nitrate
- Lime water
- Phenolphthalein solution
- Potassium permanganate
- Ammonia water
- Sodium thiosulfate (Hypo)
- Fehling's solution
- Concentrated and dilute nitric acid
- Concentrated and dilute sulphuric acid
- Concentrated and dilute hydrochloric acid
- Calcium carbonate (marble chips)
- Chromium oxide
- Cobalt chloride
- Copper (metal strips)
- Copper sulfate
- Iron chloride
- Iron sulfate
- Iron oxide
- Iodine crystals
- Lead
- Lead nitrate
- Manganese dioxide
- Mercury
- Mercuric oxide
- Nickel sulfate
- Potassium chlorate
- Sodium hydroxide
- Strontium nitrate
- Sulfur
- Tin
- Zinc
- Zinc chloride

For the most part, the supplies for elementary school science can be obtained from local stores or through a general school supply source. However, some of the special equipment needs to be ordered from a scientific supply house. The following is a list of companies which can provide such items.

Carolina Biological Supply Co., Elon College, North Carolina
Cambosco Scientific Co., Brighton, Massachusetts
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Illinois
Eimer & Amend Co., Greenwich and Morton Streets, New York 14, New York

Fisher Scientific Supply Co., 717 Forbes Street, Pittsburgh 19, Pennsylvania
General Biological Supply House, 8200 South Hoyne Avenue, Chicago 20, Illinois
Pacific Laboratory Apparatus Co., 3555 Whittier Boulevard, Los Angeles 23, California
Ward's Natural Science Establishment, Inc., 3000 Ridge Road East, Rochester 9, New York
Welch Scientific Co., 1515 North Sedgwick Street, Chicago 10, Illinois

BOOKS FOR THE ELEMENTARY SCIENCE PROGRAM

Things would be in a pretty state if every time anyone wanted to learn something, he had to discover it entirely by himself. All that is known today is based upon what was learned yesterday, and the day before, and a hundred years ago, and five thousand years before that. Learning, like civilization itself, is a continuum. Newton put it well when he said: "If I have seen farther... it is by standing on the shoulders of giants." For much information, then, one must turn to books. Authors are really resource people who, while they do not themselves come into the classroom, none the less send their information both to the teachers and to the children through the medium of their writings. A most important tool for teaching science is a well chosen library.

Selecting a library of children's science books requires, first of all, a point of view or philosophy of education. The list which follows has been chosen because it fits into the plan of science education advocated by this book. There are literally hundreds of children's science books from which to choose. These two hundred titles have been carefully selected and annotated to provide a basic collection which can furnish the necessary fundamental information which teachers and children can use to develop the sound

understandings of the seven science generalizations (see chapter III) which form the foundation of the science curriculum.

The books for this basic list have been arranged in three groups: primary grades books; intermediate grades books; and reference books and texts. The primary and intermediate lists are subdivided according to the following seven topics:

Books about animals

Books about plants

Books about the earth and its atmosphere

Books about the stars and the universe

Books about people

Books about energy, machines, and materials

Books on related science topics

Of course, categorizing books as being suitable either for primary level or for intermediate level is always a dangerous procedure and is necessarily arbitrary. There are primary grades children who can and should use books from the upper grades. There are books which are listed as being for the primary grades which can provide information for fourth, fifth, sixth, and even seventh grade classes. And, of course, there are children in the intermediate grades who are reading at more elementary levels and need easier books. Thus, when teachers use this list, they should use it as a whole. All of the books on a given topic should be taken into account as a teacher plans his work.

The reference books and texts are useful at all grade levels, and, if possible, there should be enough copies of these books available so that they are a part of the permanent library of each classroom. Certainly, copies of these books belong in the school library and should circulate to the various classrooms as they are needed.

PRIMARY GRADES BOOKS

Books about animals:

ADELSON, LEONE, *All Ready for Winter.* New York: David McKay, 1952. *A simple story of what happens to animals as winter approaches.*

BLOUGH, GLENN O., *After the Sun Goes Down.* New York: McGraw-Hill, 1956. The night-time activities of a variety of living creatures.

——, *Who Lives in this House?* New York: McGraw-Hill, 1957. A simple story of animals and how they build their homes, rear their young, and live together.

BRIDGES, WILLIAM, *Zoo Babies.* New York: Morrow, 1953. Photographs and stories of baby animals in the zoo.

BRONSON, WILFRED S., *Coyotes.* New York: Harcourt, Brace, 1946. Excellent information about a strange and interesting animal.

——, *Pollywiggle's Progress.* New York: Macmillan, 1932. The life cycle of a bull frog told accurately and placed in a scientifically accurate natural setting.

BUFF, MARY, and CONRAD BUFF, *Dash and Dart.* New York: Viking, 1942. The first year in the life of two fawns. A combination of fine artistry and good science.

——, *Elf Owl.* New York: Viking, 1958. Desert life as seen by a pair of elf owls.

——, *Hurry, Skurry, and Flurry.* New York: Viking, 1954. Another beautiful story, well told; this time about three little squirrels.

CLARK, MARY LOU, *True Book of Dinosaurs.* Chicago: Childrens Press, 1955. A book about dinosaurs which primary graders can read as well as look at.

EBERLE, IRMENGARDE, *Robins on the Window Sill.* New York: Crowell, 1958. A simple text and photo story on the life cycle of a pair of robins from arrival in springtime through mating, nesting, family life, and flight of the fledglings.

FLACK, MARJORIE, *Tim Tadpole.* New York: Doubleday, 1934. The development of a tadpole into a singing, jumping frog.

GALL, ALICE, and FLEMING CREW, *All the Year Round.* Fair Lawn, N.J.: Oxford, 1944. Simple stories of birds and small animals throughout the year.

——, *Little Black Ant.* Fair Lawn, N. J.: Oxford, 1936. An imaginative and scientifically accurate study of the ant.

HOKE, JOHN, *First Book of Snakes.* New York: Franklin Watts, 1952. An elementary but rather comprehensive study of snakes.

HUNTINGTON, HARRIET E., *Let's Go Outdoors.* New York: Doubleday, 1939. A story in photographs and simple text of the small animals found almost everywhere.

——, *Let's Go to the Brook.* New York: Doubleday, 1952. Animals and plants of a small stream, told in photographs with a simple text.

——, *Let's Go to the Desert.* New York: Doubleday, 1949. Desert animals and plants in photographs and simple text.

——, *Let's Go to the Seashore.* New York: Doubleday, 1941. A charming and accurate story in words and photographs of the common animals and birds of the sea.

——, *Praying Mantis.* New York: Doubleday, 1957. A group of exceptional photographs and simple but well written text telling the story of this interesting insect through its entire life cycle.

MCCLUNG, ROBERT M., *Bufo; the Story of a Toad.* New York: Morrow, 1954. The first three years of the life of a toad.

——, *Ruby Throat; the Story of a Hummingbird.* New York: Morrow, 1950. The life cycle of the tiny and beautiful bird told simply and accurately.

——, *Tiger; the Story of a Swallowtail Butterfly.* New York: Morrow, 1953. Accurate information about the life cycle of a butterfly, from egg to maturity, told in simple text and pictures.

PODENDORF, ILLA, *True Book of Insects.* Chicago: Childrens Press, 1954. Interesting facts about a variety of insects told in simple language and well illustrated.

——, *True Book of Pets.* Chicago: Childrens Press, 1954. The needs and care of a variety of pets.

SELSAM, MILLICENT, *All About Eggs.* New York: Scott, 1952. The story of reproduction told in simple and clear language; first chickens and birds, then dogs, cows, and whales, and finally humans.

——, *Time for Sleep.* New York: Scott, 1953. How animals rest and why they need to do it.

TABER, GLADYS, *First Book of Cats.* New York: Franklin Watts, 1950. All different kinds of cats along with their needs and care.

WILLIAMSON, MARGARET, *First Book of Birds.* New York: Franklin Watts, 1951. Information about the characteristics and features of birds.

——, *First Book of Bugs.* New York: Franklin Watts, 1949. Wide range of accurate and absorbing information on many kinds of bugs and insects.

ZIM, HERBERT S., *Elephants.* New York: Morrow, 1946. The essential facts about the elephant's life and habits, well written with excellent illustrations.

——, *Owls.* New York: Morrow, 1950. All kinds of information about all kinds of owls.

Books about plants:

BLOUGH, GLENN O., *Wait for the Sunshine.* New York: McGraw-Hill, 1954. How plants live and grow and the part that sunshine and seasons play in their growth.

HUNTINGTON, HARRIET E., *Let's Go to the Brook.* New York: Doubleday, 1952. Plant and animal life in a small stream told in photographs and simple text.

——, *Let's Go to the Desert.* New York: Doubleday, 1949. Desert plants and animals in photographs and simple text.

PODENDORF, ILLA, *True Book of Trees.* Chicago: Childrens Press, 1954. How trees grow; what they are used for; how to identify them.

——, *True Book of Weeds and Wild Flowers.* Chicago: Childrens Press, 1955. Colorful illustrations and simple text identify the weeds and wild flowers around the house, the road, the woods, and the fields.

SELSAM, MILLICENT, *Play with Plants.* New York: Morrow, 1949. Simple experiments which explain how plants and seeds live and grow.

WEBBER, IRMA E., *Bits That Grow Big.* New York: Scott, 1949. Experiments in plant reproduction in simple text and pictures.

——, *Travelers All.* New York: Scott, 1944. A simple, clear, well-written story of how plants and seeds move from place to place.

——, *Up Above and Down Below.* New York: Scott, 1943. The structure and function of plants told in pictures and text for primary graders.

——, *Thanks to Trees.* New York: Scott, 1952. The conservation story for very young readers.

ZIM, HERBERT S., *What's Inside of Plants.* New York: Morrow, 1952. Material on the physiology of plants, concise text and good illustrations.

Books about the earth and its atmosphere:

BATE, NORMAN, *Who Fishes for Oil?* New York: Scribner, 1955. The actual process of drilling an off-shore oil well.

BLOUGH, GLENN O., *Not Only for Ducks.* New York: McGraw-Hill, 1954. A simple story of the water cycle and many forms of life which are dependent upon it.

——, *Wait for the Sunshine.* New York: McGraw-Hill, 1954. The sun and the seasons and their effect on plants.

GOUDEY, ALICE E., *Good Rain.* New York: Aladdin Books, 1950. What rain does for people both in city and in the country.

NORLING, JOSEPHINE S., *First Book of Water.* New York: Franklin Watts, 1952. Water from clouds, snow, ice, rivers, oceans; the work done by water; simple experiments with water.

Books about the stars and the universe:

MEYER, JEROME S., *Picture Book of Astronomy.* New York: Lothrop, Lee, and Shepard, 1945. A young reader's introduction to the subject of astronomy.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *You Among the Stars.* New York: Scott, 1951. Simple explanations of the earth, the solar system, and the universe.

Books about people:

GRUENBERG, SIDONIE M., *Wonderful Story of How You Were Born.* New York: Garden City Books, 1952. The simply told and accurate story of human reproduction. Excellent for use with primary grades or for recommendation to parents for use when a new sibling is expected.

HOGBEN, LAUNCELOT T., with MARIE NEURATH and J. A. LAUWERYS, *How the First Men Lived.* New York: Chanticleer, 1950. The story of pre-historic man—how he hunted, built shelters, made tools and weapons, discovered fire.

SELSAM, MILLICENT, *All About Eggs.* New York: Scott, 1952. The story of reproduction including a short and simple explanation of human reproduction.

ZIM, HERBERT S., *What's Inside of Me?* New York: Morrow, 1952. How the internal organs of the human body function.

Books about energy, machines, and materials:

ELTING, MARY, *Lollypop Factory—and Lots of Others.* New York: Doubleday, 1946. The basic principles of science which are involved in the modern industrial production system.

HAMILTON, RUSSEL, *First Book of Trains.* New York: Franklin Watts, 1956. A review of different kinds of trains and their various functions.

NIGHBERT, ESTHER, *True Book of Cloth.* Chicago: Childrens Press, 1955. The story of all kinds of cloth from both natural and synthetic fibres.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *Now Try This.* New York: Scott, 1947. Elementary mechanics, including friction, levers, wheels, etc., with simple experiments to demonstrate the science principles.

SCHNEIDER, NINA, and HERMAN SCHNEIDER, *Let's Find Out.* New York: Scott, 1946. A book of simple physics concepts and experiments to explain the concepts.

ZIM, HERBERT S., *Things Around the House.* New York: Morrow, 1954. The science involved in common household items.

Books about related science topics:

BEHN, HARRY, *All Kinds of Time.* New York: Harcourt, Brace, 1950. Time from a child's view point—clocks, seasons, years.

BENDICK, JEANNE, *All Around You.* New York: McGraw-Hill, 1951. A pleasing picture book about the natural phenomena which a child sees around him—sun, moon, clouds, water, soil, seeds, etc.

LEAF, MUNRO, *Arithmetic Can Be Fun.* Philadelphia: Lippincott, 1949. Some of the whys and hows of arithmetic, including telling time, measurement, reading the calendar, and money.

NEURATH, MARIE, *I'll Show You How It Happens.* New York: Lothrop, Lee, and Shepard, 1949. Simple explanations of many science phenomena including a number from the physical sciences such as steam locomotives and canal locks.

PARKER, BERTHA M., *Golden Book of Science.* New York: Simon and Schuster, 1956. A peek at the many phases of science which interest the beginner; profusely and well illustrated.

PODENDORF, ILLA, *True Book of Science Experiments.* Chicago: Childrens Press, 1954. Simple experiments about air, magnets, water, sound, gravity, heat and cold, using materials found around the house.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *How Big Is Big?* New York: Scott, 1950. Ideas on big and small which go from the familiar to the unknown in step by step comparisons. For more mature primary graders.

INTERMEDIATE GRADES BOOKS

Books about animals:

ANDREWS, ROY C., *All About Whales.* New York: Random House, 1954. All kinds of whales and whaling—where these creatures live and their habits.

BULLOUGH, WILLIAM, and HELENA BULLOUGH, *Introducing Animals-*

with-Backbones, New York: Crowell, 1954. The 350 million years of back-boned life from the earliest known fishes to man himself.

EARLE, OLIVE L., *Birds and Their Nests*. New York: Morrow, 1952. Characteristics, nesting habits, common locations, and other materials on more than 40 birds of North America.

HOGNER, DOROTHY C., and NILS HOGNER, *Animal Book: American Mammals North of Mexico*. Fair Lawn, N. J.: Oxford, 1942. The appearance, habits, and behavior of North American mammals along with their economic significance.

HOLLING, HOLLING C., *Minn of the Mississippi*. Boston: Houghton Mifflin, 1951. The 2500 miles of the Mississippi River are described in parallel to the life of a snapping turtle who lives in it.

HYLANDER, CLARENCE J., *Animals in Armor*. New York: Macmillan, 1954. An introduction to the common reptiles, where and how they live, and their place in nature.

KIERAN, MARGARET F., and JOHN KIERAN, *John James Audubon*. New York: Random House, 1954. The life story of the man who studied and made so many colorful paintings of American birds.

MATHEWS, FERDINAND S., *Book of Birds for Young People*. New York: Putnam, 1921. A general discussion of the birds of eastern North America, including a fine chapter on migration of birds.

MORGAN, ALFRED P., *Aquarium Book for Boys and Girls*. New York: Scribner, 1936. A good working handbook on the care and feeding of common aquarium fish.

PISTORIUS, ANNA, *What Butterfly Is It?* Chicago: Follett, 1949. Accurate information about more than 50 common butterflies of North America. An excellent beginning reference.

POPE, CLIFFORD H., *Reptiles Round the World*. New York: Knopf, 1957. The ways of reptiles and their distribution around the world.

ROBERTSON, GLADYS V., *Strange Sea Life*. New York: Henry Holt, 1950. The strange creatures that inhabit the sea, well described and illustrated.

SANDERSON, IVAN T. (ed.), *Animal Tales*. New York: Knopf, 1946. An anthology of animal tales from many countries with descriptions of the locales and a brief sketch of the author of each story.

ZIM, HERBERT S., *Goldfish.* New York: Morrow, 1947. A simple, scientific explanation of the nature and kinds of goldfish along with excellent instructions on how to care for them.

——, *Reptiles and Amphibians.* New York: Simon and Schuster, 1953. One of the *Golden Nature Guide* series which, for simple identification materials, is excellent.

Books about plants:

BEATY, JOHN Y., *Luther Burbank, Plant Magician.* New York: Messner, 1943. The story of the man who developed many new varieties of plants.

BUCK, MARGARET W., *In Ponds and Streams.* Nashville, Tenn.: Abingdon Press, 1955. A fine elementary description of the flora and fauna to be found on and around small bodies of water.

BUFF, MARY, and CONRAD BUFF, *Big Tree.* New York: Viking Press, 1946. A beautifully told story of the 5000-year life of a giant sequoia.

CORMACK, MARIBELLE, *First Book of Trees.* New York: Franklin Watts, 1951. A simple guide for the identification and location of many common trees of America.

LIMBACK, RUSSELL T., *American Trees.* New York: Random House, 1942. Full page color illustrations and many large drawings of leaves and fruits of trees make this a very useful guide.

SCHATZ, ALBERT, and SARAH RIEDMAN, *Story of Microbes.* New York: Harper, 1952. A readable and informative text on micro-organisms—their discovery, their nature, their impact on humans.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *Plants in the City.* New York: John Day, 1951. The plants and trees that live and grow in the city described in text and illustrations along with simple experiments to explain various phases of plant growth.

SELSAM, MILLICENT, *Microbes at Work.* New York: Morrow, 1953. The work that micro-organisms do and how this work affects man is explained with text, illustrations, and some simple experiments.

——, *Plants We Eat.* New York: Morrow, 1955. The history of our various food plants along with scientific phenomena related to these plants. Includes simple experiments.

STERLING, DOROTHY, *Story of Mosses, Ferns, and Mushrooms.* New York: Doubleday, 1955. Photographs and well-written text give the story and facts about flowerless plants.

WOOD, LAURA N., *Louis Pasteur.* New York: Messner, 1948. A warmly human story of the man who worked with microbes.

Books about people:

BECK, LESTER F., *Human Growth.* New York: Harcourt, Brace, 1949. Growth, reproduction, and sex instruction based on an educational film of the same title.

BENEDICT, RUTH F., and GENE WELTFISH, *In Henry's Backyard.* New York: Abelard-Schuman, 1948. The differences among races and the origins of racial prejudices told by two famous anthropologists.

EBERLE, IRMENGARDE, *Big Family of Peoples.* New York: Crowell, 1952. The tides of people sweep back and forth over the earth and make up one race—the human race.

EDEL, MAY M., *Story of our Ancestors.* Boston: Little, Brown, 1955. Prehistoric man's story and how it has been pieced together.

EVANS, EVA, *All About Us.* Irvington-on-Hudson, N.Y.: Capitol, 1947. Scientific facts about people and groups, designed to combat predjudices.

JESSUP, RONALD F., *Wonderful World of Archaeology.* New York: Garden City Books, 1956. The story of archaeology, its relationship to the modern world, and the modern scientific tools which men use to find out about ancient civilizations.

KUBIE, NORA B., *First Book of Archaeology.* New York: Franklin Watts, 1957. An elementary look at lost civilizations and ancient cities, and the men who uncover these stories of the past.

LEVINE, MILTON I., and JEAN H. SELIGMANN, *A Baby Is Born.* New York: Simon and Schuster, 1949. A frank story of how life begins, simply and directly told without sentimentality.

RAVIELLI, ANTHONY, *Wonders of the Human Body.* New York: Viking, 1954. The human body as a machine; a clear and well-written explanation of the structure and function of the whole body and its various parts.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *How Your Body Works.* New York: Scott, 1949. The digestive system and the sensory system explained fully in terms that are accurate but simple.

SCHNEIDER, LEO, *You and Your Senses.* New York: Harcourt, Brace, 1956. Explanations and simple experiments to show how your senses work.

SHIPPEN, KATHERINE B., *Men of Medicine.* New York: Viking, 1957. The lives and works of major medical scientists of the past five thousand years.

STRAIN, FRANCES B., *Being Born.* New York: Appleton-Century-Crofts, 1954. Sex instruction and information about hospital care for mothers and babies.

ZIM, HERBERT S., *Our Senses and How They Work.* New York: Morrow, 1956. An elementary but accurate study of the human sense organs.

Books about the earth and its atmosphere:

ANDREWS, ROY C., *All About Dinosaurs.* New York: Random House, 1953. An expert tells about fossils and the excitement of hunting them.

BATTY, ELIZABETH C., *America Before Man.* New York: Viking, 1953. The geologic history of the western hemisphere.

BELL, THELMA H., *Snow.* New York: Viking, 1954. How snow and its related forms of precipitation are developed and fall to earth.

BRINDZE, RUTH, *Gulf Stream.* New York: Vanguard, 1945. The ocean river that is a determinant of man's Atlantic voyages told in simple text and pictures.

COLEMAN, SATIS N., *Volcanoes, New and Old.* New York: John Day, 1946. An excellent reference work on the volcanoes of the world.

CORMACK, MARIBELLE, *First Book of Stones.* New York: Franklin Watts, 1950. A beginner's look at rocks and how to make a rock collection.

FENTON, CARROLL L., and MILDRED A. FENTON, *Land We Live On.* New York: Doubleday, 1944. The story, very simply told, of the land, how it came to be, and how it is changed by fire, water, air, and men.

——, *Prehistoric World.* New York: John Day, 1954. Stories of animal life in past ages.

——, *Rocks and Their Stories.* New York: Doubleday, 1951. As fine an introduction to physical geology and the nature of rocks, stones, minerals, ores and the other materials of the earth's surface as is to be found.

Fisher, James, *Wonderful World of the Sea.* New York: Garden City Books, 1957. The natural phenomena of the sea, the life within it, and its potential for men.

Gaer, Joseph, *Everybody's Weather.* Philadelphia: Lippincott, 1944. Weather phenomena and how they are related to various occupations.

Gallant, Roy A., *Exploring the Weather.* New York: Garden City Books, 1957. A worthwhile addition to the collection of children's books about the weather.

Galt, Thomas F., *Volcano.* New York: Scribner, 1946. The story of Paricutin and its rise from a cornfield to a volcano.

Graham, Edward H., *Water for America.* Fair Lawn, N.J.: Oxford, 1956. The story of water, with particular emphasis on its conservation aspects.

Hyde, Margaret O., *Exploring Earth and Space.* New York: McGraw-Hill, 1957. The various aspects of earth and space study related to the International Geophysical Year.

Pough, Frederick H., *All About Volcanoes and Earthquakes.* New York: Random House, 1953. A survey of volcanoes and earthquakes and what they do to and for men.

Reed, W. Maxwell, *Earth for Sam.* New York: Harcourt, Brace, 1930. A children's classic on the geologic periods of the earth.

——, *Sea for Sam.* New York: Harcourt, Brace, 1935. Oceanography in all its aspects told very well for beginning scientists.

Riedman, Sarah, *Water for People.* New York: Abelard-Schuman, 1952. Water and how it serves men for food production, power, and other ways.

Schneider, Herman, and Nina Schneider, *Everyday Weather and How it Works.* New York: McGraw-Hill, 1951. Weather phenomena and the science which explains them. A simple weather station is planned and suggestions for building it are given.

——, *Rocks, Rivers and the Changing Earth.* New York: Scott, 1952. Historical and economic geology made understandable through good text, illustrations, and simple experiments.

TANNEHILL, IVAN R., *All About the Weather.* New York: Random House, 1953. The work of the weatherman in observing, measuring, reporting, predicting, and warning.

TANNENBAUM, BEULAH, and MYRA STILLMAN, *Understanding Maps.* New York: McGraw-Hill, 1957. How the earth is mapped and the ways that men use maps. Simple experiments to determine latitude and longitude.

WHITE, ANNE TERRY, *Prehistoric America.* New York: Random House, 1951. America before the Indians reached these shores when prehistoric monsters roamed here.

WYLER, ROSE, and GERALD AMES, *Story of the Ice Age.* New York: Harper, 1956. The fascinating account of the various ice ages along with some of the theories of how ice ages came to be, and their effect on plant, animal, and human life.

ZIM, HERBERT S., *Dinosaurs.* New York: Morrow, 1954. A complete discussion of the age of reptiles.

——, *Lightning and Thunder.* New York: Morrow, 1952. A fine explanation of a topic which while difficult is none the less of great interest to all children.

ZIM, HERBERT S., and ELIZABETH K. COOPER, *Minerals; Their Identification, Uses, and How to Collect Them.* New York: Harcourt, Brace, 1943. Excellent for simple identification of common minerals.

Books about the stars and the universe:

BAKER, ROBERT H., *When the Stars Come Out.* New York: Viking, 1954. A recognized astronomer tells the story of that science from its earliest beginnings to the present.

BRINDZE, RUTH, *Story of Our Calendar.* New York: Vanguard, 1949. The development of our calendar from the Babylonians to the present.

FENTON, CARROLL L., and MILDRED A. FENTON, *Worlds in the Sky.* New York: John Day, 1950. A simple study of the earth in space, beginning with the earth and its movements and going on to the sun, its planets, the stars, and the galaxies.

ics. New York: Crowell, 1954. Simple experiments and explanations of atomics.

——, *Experiments with Electricity.* New York: Crowell, 1949. More than twenty safe experiments with electricity together with explanations of the principles which they demonstrate.

Bendick, Jeanne, *Electronics for Young People.* New York: McGraw-Hill, 1955. An introduction to electronics—what electrons are, how they work, and how they are harnessed.

——, *First Book of Airplanes.* New York: Franklin Watts, 1952. An introduction to aviation—its basic science principles and their applications.

——, *First Book of Space Travel.* New York: Franklin Watts, 1953. The meaning of space and the problems that must be overcome in order for man to explore it.

Bendick, Jeanne, and Robert Bendick, *Television Works Like This.* New York: McGraw-Hill, 1954. The operation of a television system from studio to home including chapters on color television and network systems.

Britten, Katherine, *What Makes It Tick?* Boston: Cadmus, 1943. The hows and whys of many common mechanical devices.

Bischof, George P., *Atoms at Work.* New York: Harcourt, Brace, 1951. Basic principles and the promise of atomic energy, simply told.

Burlingame, Roger, *Machines That Built America.* New York: Harcourt, Brace, 1953. The story of mass production and the men, machines, and materials that made it possible.

Coggins, Jack, and Fletcher Pratt, *Rockets, Jets, Guided Missiles, and Space Ships.* New York: Random House, 1951. History and development of rockets and jets, along with an explanation of their operation.

Doorly, Eleanor, *The Radium Woman; A Life of Marie Curie.* New York: Roy Publishers, 1955. A thoroughly readable book about Mme. Curie's struggle against poverty and her dedication to physics.

Fenton, Carroll L., and Mildred A. Fenton, *Riches from the Earth.* New York: John Day, 1953. Important ores, compounds, and elements, and how they are made useful for men.

FREEMAN, MAE, and IRA FREEMAN, *Fun with Chemistry*. New York: Random House, 1944. A first laboratory book of chemistry.

——, *Fun with Science*. New York: Random House, 1943. Simple experiments and experiences which can help children understand simple physical principles.

GRAHAM, SHIRLEY, *Dr. George Washington Carver, Scientist*. New York: Messner, 1944. The story of how the son of a slave strove to educate himself and finally became a distinguished chemist.

HOGBEN, LANCELOT T., *Wonderful World of Energy*. New York: Garden City Books, 1957. Man's use of power from earliest times to atomic energy.

HUEY, EDWARD G., *What Makes the Wheels Go Round*. New York: Harcourt, Brace, 1952. A simple overview of some physics principles and their applications to many common phenomena.

JUDSON, CLARA, *Benjamin Franklin*. Chicago: Follett, 1957. Emphasizes mostly his political achievements, but does list his scientific discoveries and inventions.

LEWELLEN, JOHN B., *Helicopters; How They Work*. New York: Crowell, 1954. The way helicopters work and the uses to which they can be put.

——, *Mighty Atom*. New York: Knopf, 1955. A very simple and clear explanation of the atom and methods for releasing its energy.

——, *Understanding Electronics*. New York: Crowell, 1957. A good but difficult book on electronics and how it has affected man's life.

——, *You and Atomic Energy*. Chicago: Children's Press, 1949. Very good explanation of the development and uses of atomic furnaces.

LEY, WILLY, *Engineers' Dreams*. New York: Viking, 1954. The projects that engineers have planned but never carried out—a glimpse into the never-never-world of science dreams.

MAGINLEY, C. J., *Historic Models of Early America*. New York: Harcourt, Brace, 1947. A historic sketch along with detailed plans for constructing many of the tools and machines of early America.

MEADOWCROFT, WILLIAM H., *Boy's Life of Edison*. New York: Harper, 1926. This is practically an autobiography of Thomas Edison since he worked very closely with the author.

MORGAN, ALFRED P., *First Electrical Book for Boys*. New York: Scribner, 1951. A comprehensive story of electricity with many facets which children can explore.

NEURATH, MARIE, *Rockets and Jets*. New York: Lothrop, Lee, and Shepard, 1952. Elementary explanation of the principles of rockets and jets and how the principles have been applied to aircraft.

POOLE, LYNN, *Your Trip into Space*. New York: McGraw-Hill, 1953. Scientific information on space travel and what it will mean to men in the future.

REYNOLDS, QUENTIN J., *Wright Brothers; Pioneers of American Aviation*. New York: Random House, 1950. The story of how the brothers invented, built, and flew the first airplane.

ROSEN, SIDNEY, *Galileo and the Magic Numbers*. Boston: Little, Brown, 1958. Galileo's struggle to introduce his ideas in hostile 16th century Italy.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *Let's Look Inside Your House*. New York: Scott, 1948. Simple text and experiments which explain the common household physics phenomena.

——, *More Power to You*. New York: Scott, 1953. The significant factors in the development of power from windmills to atomic furnaces.

——, *Your Telephone and How It Works*. New York: McGraw-Hill, 1952. A careful and logical explanation of sound and how it is transformed into electricity through the medium of the telephone.

SHIPPEN, KATHERINE B., *Bridle for Pegasus*. New York: Viking, 1951. Stories of man's attempts to fly.

——, *Mr. Bell Invents the Telephone*. New York: Random House, 1952. A well-written story of the dedicated life of the inventor of the telephone.

SOOTIN, HARRY, *Michael Faraday; From Errand Boy to Master Physicist*. New York: Messner, 1954. The story of the British scientist who developed the dynamo, the electric motor, etc.

STODDARD, EDWARD, *First Book of Television*. New York: Franklin Watts, 1955. A simple explanation of what television is and how it works.

TANNENBAUM, BEULAH, and MYRA STILLMAN, *Isaac Newton, Pioneer of Space Mathematics*. New York: McGraw-Hill, 1959. A fascinating story of the life of Isaac Newton with special attention to his scientific achievements in the fields of physics and mathematics.

Books on related science topics:

BENDICK, JEANNE, *How Much and How Many*. New York: McGraw-Hill, 1947. How weights and measures affect science and everyday living.

CROUSE, WILLIAM H., *Understanding Science*. New York: McGraw-Hill, 1956. The scientific laws that govern the operations of many of the man-made and natural science phenomena of the world.

HOGBEN, LANCELOT T., *Wonderful World of Mathematics*. New York: Garden City Books, 1955. Mathematics as men have discovered it and invented it.

POOLE, LYNN, *Frontiers of Science*. New York: McGraw-Hill, 1958. The areas of science which will be tomorrow's work-a-day world: computers, chemurgy, solar energy, etc.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *Science Fun with Milk Cartons*. New York: McGraw-Hill, 1953. How to build models of many scientific devices with milk cartons and a few tools.

SCHWARTZ, JULIUS, *It's Fun to Know Why*. New York: McGraw-Hill, 1952. Safe and easy-to-do experiments which illustrate the properties of many common substances.

SHIPPEN, KATHERINE B., *Bright Design*. New York: Viking, 1949. Biographies of many scientists who worked in physics from the medieval period to the present.

——, *Great Heritage*. New York: Viking, 1947. The resources of America and how they have been and are being used.

REFERENCE BOOKS AND TEXTS

COMSTOCK, ANNA, *Handbook of Nature Study*. Ithaca, N.Y.: Comstock Publishing Co., 1939 (24th ed). The classic in the field of nature study; about as complete a guide to nature as one can find in

a single volume. (The lesson plans are out of date, and you will probably not want to use them.)

CRAIG, GERALD S., et al., *Science Today and Tomorrow*. Boston: Ginn, 1954. A basic text series with enough varied and interesting material to be very useful both to children and teachers.

PARKER, BERTHA M., *Golden Treasury of Natural History*. New York: Simon and Schuster, 1952. An encyclopedic volume of information on animal and plant life from prehistoric time to the present. Excellent for beginning reference work.

PARKER, BERTHA M., et al., *Basic Science Education Series*. Evanston, Ill.: Row, Peterson. An excellent group of pamphlets on a great variety of science topics.

SCHNEIDER, HERMAN, and NINA SCHNEIDER, *Heath Elementary Science Series*. Boston: Heath, 1955. Well-written text materials in a wide ranging elementary science program. Good materials for the gifted child.

TANNENBAUM, HAROLD E., and NATHAN STILLMAN, *Webster Junior Science Library*. St. Louis, Mo.: Webster, 1960. Science pamphlets on a wide variety of topics, written especially for the primary grades. Give accurate information through simple text and colorful illustrations. Includes experiments and suggestions for further work.

THURBER, WALTER A., *Exploring Science*. Boston: Allyn and Bacon, 1955. The simplest, clearest, and most comprehensive elementary science texts that have appeared thus far.

WARE, KAY, and LUCILLE SUTHERLAND, *Webster Classroom Science Library*. St. Louis, Mo.: Webster, 1957. Exciting colored illustrations and text explaining many natural phenomena in 32-page pamphlets. Include suggestions for science hobbies.

WRITER'S PROGRAM, *Birds of the World; Who's Who in the Zoo;* and *Reptiles and Amphibians*. New York: Whitman, 1950. Photographs and scientifically accurate non-technical text describe these animals for children.

ZIM, HERBERT S., *Golden Nature Guide Series*. New York: Simon and Schuster. Simply organized and inexpensive guides in full color to Birds, Flowers, Insects, Stars, Trees, Reptiles and Amphibians, and Fishes.

FILMS FOR THE ELEMENTARY SCIENCE PROGRAM

Another useful tool is the motion picture. Here is a means of showing the dynamic action of an event, of showing a living organism in its life-like situations. This kind of device is a boon to the teacher. American teachers generally cannot take their students to see real glaciers. But the students can see glaciers in action through the medium of a good film. Students cannot observe tornadoes at first hand or wait for time-lapse events with growing plants. But films can hring these phenomena to them. A good film is a way of hringiog an event from the outside world into the classroom when it is appropriate for the science program.

There are, in the United States, many hundreds of sources for films. Small film libraries are to be found in almost every location. But there are a few major film libraries which can furnish almost all the films an elementary science program requires. The following list contains some of the major reotal libraries across the country.

University audio-visual centers

University of Arizona, Tucson, Arizona
Boston University, Boston, Massachusetts
Columbia University, New York, New York
University of California, Berkeley, California
University of Illinois, Champaign, Illinois
University of Indiana, Bloomington, Indiana
Iowa State University, Iowa City, Iowa
University of Minnesota, Minneapolis, Minnesota
University of Mississippi, University, Mississippi
Ohio State University, Columbus, Ohio
Pennsylvania State University, University Park, Pennsylvania
Syracuse University, Syracuse, New York
University of Texas, Austin, Texas
West Virginia University, Morgantown, West Virginia

Private, non-profit film libraries

American Museum of Natural History, New York, New York
Association Films, Ridgefield, New Jersey
Moody Institute of Science, West Los Angeles, California

Private film libraries

Ideal Picture Corporation, New York, New York
International Film Bureau, Chicago, Illinois
United World Films, New York, New York

Furthermore, state education departments often have extensive film libraries which are available to teachers of that state. Various federal government agencies such as the Department of Defense, the Department of the Interior, the Atomic Energy Commission and many others have films which can be obtained free or at a nominal cost. In addition to these sources, there are thousands of free films available to teachers from private business corporations, special foundations, and the like. Of course, these films will be, in many cases, of no use because of their specialized or advanced contents. However, there are many that can be used very profitably. For example, the Bell Telephone Company has produced a number of science television programs, and the Kinescopes of these programs are distributed free through the public relations offices of the company. A complete listing of free films may be found in:

Educator's Guide to Free Films. Randolph, Wisconsin: Educator's Progress Service.

As with books, there are a multitude of fine films which can be used in the classroom. The films which have been selected for inclusion in this list fit into the kind of science program that has been proposed. Each film is annotated and has been classified with regard to both appropriate grade level and subject matter. The following abbreviations are used in the list:

P — primary grades
I — intermediate grades
B/W — black and white
E.B.F. — Encyclopaedia Britannica Films

Films about animals, plants, and people:

ANIMALS IN SPRING. P & I; 1 reel (color or B/W); E.B.F.
The effects of springtime on the lives and habits of common animals.

ANIMALS IN SUMMER. P & I; 1 reel (color or B/W); E.B.F.
How summer affects some common animals.

ANIMALS IN WINTER. P & I; 1 reel (color or B/W); E.B.F.
How animals prepare to survive the winter.

ANTS—UNDERGROUND FARMERS. I; 1 reel (B/W); Library Films.
Excellent photography of an ant colony and how its work is organized.

BALANCED AQUARIUM, A. P. & I; 1 reel (color or B/W); E.B.F.
Setting up an aquarium and watching the resultant growth of plants and fish.

BEAVER VALLEY. P & I; 3 reels (color); Walt Disney Productions.
The life story of the beaver, how he lives, raises his young, and protects his home; description of his general surroundings.

BIRDS OF THE COUNTRYSIDE. P & I; 1 reel (color or B/W); Coronet.
Some of the common birds and how they live; what they eat, how they nest, their calls, how they raise their young.

BLACK BEAR TWINS. P & I; 1 reel (B/W); E.B.F.
A delightful study of two bear cubs as they play in a national park.

BOUNDARY LINES. I; 1 reel (color); Julian Bryan Productions.
A study of how racial and religious prejudices grow and develop.

EGGS TO CHICKENS. I; 1 reel (B/W); Bailey Films.
How a chick is hatched from the union of a hen and rooster. Excellent close-up photographs of the development of an embryo.

GIFT OF GREEN, THE. I; 1 reel (color); Sugar Research Foundation.
Green plants and their significance for life told simply and in nontechnical language.

HOUSE-FLY, THE. I; 1 reel (color or B/W); E.B.F.
Micro-photography used to show the habits and life cycle of the common house-fly and how it is a menace to health.

HOW OUR BODIES FIGHT DISEASE. I; 1 reel (B/W); E.B.F.
The various protective organs such as skin and mucous membranes and how they are used to fight off illnesses.

LIFE IN A DROP OF WATER. I; 1 reel (color or B/W); Coronet.
Simple micro-organisms used to explain the basic necessities of animal life.

LIVING AND NON-LIVING THINGS. P; 1 reel (color or B/W); Coronet.
The differences between these two major groups. Very simple.

MAMMALS ARE INTERESTING. I; 1 reel (color or B/W); E.B.F.
The distinctive characteristics of many animals along with the ways in which animals are classified.

PLANT GROWTH. I; 1 reel (B/W); E.B.F.
Time-lapse photography and animated drawings show the growth of plants from seed to flower opening.

PRAYING MANTIS. P & I; 1 reel (color); Bailey Films.
An interesting story of the life cycle of this amazing insect.

SEEDS GROW INTO PLANTS. P; 1 reel (color or B/W); Coronet.
The stages of plant development from seed to maturity and the conditions necessary for such development.

SLEEP FOR HEALTH. P & I; 1 reel (B/W); E.B.F.
Sleep and its importance in our health habits.

Films about the earth, the stars, and the universe:

AIR ALL AROUND US. I; 1 reel (B/W); Young America Films.
Simple experiments to show that air occupies space, has weight, expands and contracts, and can be compressed.

AIR AROUND US, THE. P & I; 1 reel (color or B/W); E.B.F.
The reality of air is shown along with its nature, uses, and chemical composition.

BIG SUN AND OUR EARTH, THE. P; 1 reel (color or B/W); Coronet.
A very simple explanation of the importance of the sun and the work it does for us.

CLOUDS ABOVE. P & I; 1 reel (B/W); Bailey Films.
The four main types of clouds and their significance.

EXPLORING THE NIGHT SKY. I; 1 reel (B/W); E.B.F.
The stars and constellations, including how they got their names; also material on how the calendar was made.

FORCES OF GRAVITY, THE. I; 1 reel (B/W); Young America Films.
An explanation of gravity and its observable effects.

FOSSILS: CLUES TO PREHISTORIC TIMES. I; 1 reel (color or B/W); Coronet.
The story of how fossils came to be and how scientists have been able to find their meanings.

HOW WEATHER IS FORECAST. I; 1 reel (color or B/W); Coronet.
How a weather station uses its instruments and maps to predict the weather is explained.

LANDS AND WATER OF OUR EARTH. P; 1 reel (color or B/W); Coronet.
Land forms and waterways seen through the eyes of a child.

MAPS AND THEIR MEANING. I; 1 reel (color); Academy Films.
How maps are made, what they mean, and how they may be used.

MOON AND HOW IT AFFECTS US, THE. I; 1 reel (color or B/W); Coronet.
A fine explanation of the moon's phases along with excellent telescopic photographs of the moon. Good explanation of tides.

MOUNTAIN BUILDING. 6th grade and up; 1 reel (B/W); E.B.F.
The story of mountains, shown along with the geologic evidence which told the story.

SEASONS OF THE YEAR, THE. P; 1 reel (color or B/W); Coronet.
How the seasons change and what the changes mean to men.

SOLAR SYSTEM, THE. 6th grade and up; 1 reel (B/W); Coronet.
The planets and their places in the solar system presented through the use of models. Various basic concepts such as gravity and the differences between stars and planets are included.

STORY OF A STORM, A. 6th grade and up; 1 reel (color or B/W); Coronet.
A very dramatic explanation of the forces that cause a rain storm to develop.

THUNDER AND LIGHTNING. P & I; 1 reel (B/W); Young America Films.
Thunder and lightning explained with answers to the questions which children ask about these phenomena.

UNDERSTANDING OUR EARTH: GLACIERS. I; 1 reel (color or B/W); Coronet.
Different kinds of glaciers and how they now are affecting and have affected the earth.

UNDERSTANDING OUR EARTH: HOW ITS SURFACE CHANGES. I; 1 reel (color or B/W); Coronet.
The forces that build up and wear away the earth's surface.

UNDERSTANDING OUR EARTH: ROCKS AND MINERALS. I; 1 reel (color or B/W); Coronet.
The classifications of rocks—igneous, sedimentary, and metamorphic —and how they are formed and used.

UNDERSTANDING OUR EARTH: SOIL. I; 1 reel (color or B/W); Coronet.
The nature of soil and how it is formed with clear explanations of erosion and decay.

VOLCANOES IN ACTION. 6th grade and up; 1 reel (B/W); E.B.F.
The history, cause, distribution, and effects of volcanoes. Special reference to Krakatoa.

WATER, WATER, EVERYWHERE. P; 1 reel (color or B/W); Coronet.
The water that is all around us both seen and unseen, and how water is important to us.

WHAT DO WE SEE IN THE SKY? P; 1 reel (color or B/W); Coronet.
An elementary study of the things which are found in the sky—sun, moon, planets, stars.

WHAT MAKES RAIN? P & I; 1 reel (B/W); Young America Films.
The water cycle and what causes rain.

WORK OF RIVERS, THE. 6th grade and up; 1 reel (B/W); E.B.F.
A thorough description of flowing water from the water cycle through erosion and its varying results.

Films about energy, machines, and materials:

A IS FOR ATOM. I; 1 reel (color), General Electric Co.
The use of atomic energy in a variety of ways and its many promises for the future.

ENERGY FROM THE SUN. 6th grade and up; 1 reel (B/W); E.B.F.
Using photographs of the sun's surface to learn about our own star and how we use its radiant energy. Includes material on the direct use of solar energy.

HOW MACHINES AND TOOLS HELP US. P; 1 reel (color or B/W); Coronet.
A simple explanation of how man uses natural forces through the medium of machines and engines to make his work easier.

HOW MAN MADE DAY. I; 1 reel (color or B/W); E.B.F.
The story of illumination from the earliest times to the present.

JET PROPULSION. I; 1 reel (color or B/W); E.B.F.
A clear explanation of the operation of a jet engine with emphasis on Newton's third law along with the uses of the engine in modern planes.

LEARNING ABOUT ELECTRIC CURRENT. I; 1 reel (B/W); E.B.F.
The ways in which electricity is used and the devices by which it is used: circuits, conductors, insulators, fuses, switches.

LEARNING ABOUT HEAT. I; 1 reel (B/W); E.B.F.
How heat operates on various materials and how it travels.

LEARNING ABOUT LIGHT. I; 1 reel (B/W); E.B.F.
An explanation of light and how it affects various materials: transparency, luminescence, translucence, opaqueness, reflection, refraction.

LEARNING ABOUT SOUND. I; 1 reel (B/W); E.B.F.
How sounds are made, how they are transmitted, and how they are heard.

MAGNETISM. 6th grade and up; 1½ reels (B/W); E.B.F.
Magnetism and its laws, how it affects the earth and how men use it.

MAGNETS. P & I; 1 reel (B/W); Young America Films.
Children discovering magnets and what they can do.

MAKING ELECTRICITY. I; 1 reel (B/W); E.B.F.
The story of the electric generator and its theory of operation.

SIMPLE CHANGES IN MATTER. I; 1 reel (color or B/W); Coronet.
Energy and matter transformations in the everyday world. A good explanation of the difference between physical and chemical change.

STORY OF PETROLEUM, THE. I; 1 reel (B/W); E.B.F.
Petroleum discovery, production, uses, and distribution.

THEORY OF FLIGHT. I; 1 reel (B/W); E.B.F.
Why a plane can fly, shown through wind-tunnel demonstrations. Also the functions of the rudder, elevator, ailerons, etc.

UNDERSTANDING FIRE. P & I; 1 reel (color or B/W); Coronet.
The uses of fire and its characteristics, including the importance of oxygen, fuel, and heat.

WATER POWER. I; 1 reel (B/W); E.B.F.
Water as a source of power and the ways man has learned to harness it.

WHAT MAKES THINGS FLOAT? I; 1 reel (B/W); Films Inc.
The basic principles of flotation and how these principles are used by man.

OTHER AUDIO-VISUAL AIDS

In addition to films, there are other visual tools which are useful in the classroom. The most numerous and most easily acquired, and often the most useful, are pictures gathered from magazines, newspapers, and other sources. Files of pictures, pertinent articles, and pamphlets should be collected continuously. Items on science subjects from current periodicals and newspapers can provide the teacher with much background and enrichment material for his teaching.

Take, for example, a file on astronomy. In it, one might have a star chart, a pamphlet on star lore from the planetarium of the nearby natural history museum, an article or two from the magazine section of the Sunday newspaper, a set of clippings from a weekly picture magazine on stars and galaxies, notes from a college astronomy course, and newspaper clippings about the newest telescopes and the latest astronomical discoveries. Other files can be made up in the same way—a file on motors and machines, one on the Arctic, one on maps, one on birds, one on mammals, one on space travel, and so on. Files of this kind can prove invaluable.

There are also commercial still-pictures prepared especially for school use. The most common of these are slides and filmstrips. Such materials have two advantages. In the first place, and most important, they are produced by professionals. A good filmstrip is an organized body of visual material on a single topic and the photography is generally of high caliber. Secondly, either filmstrips or slides can be shown on small and relatively inexpensive machines. On the other hand, both slides and filmstrips are expensive to buy and many of the topics that they cover generally can be presented as well or better by the teacher himself with the use of an opaque projector to reproduce materials from his own files or from the library.

Slides and filmstrips generally must be purchased. They cannot be rented. And the cost of a filmstrip or of a set of slides is usually more than the cost of a well-illustrated book. Using an opaque projector, the teacher can present visual materials from a book as well as from his files and can thus have more reference material for use in his classroom. This means that the choosing of slides and filmstrips requires great discrimination. Such materials should be purchased only after they have been examined at first hand and their uses have been thoroughly considered.

Given below is a list of some major filmstrip and slide producers whose catalogs are available for the asking and whose materials have proved sound both from a technical and an educational point of view.

Filmstrip producers:

American Council on Education, 1785 Massachusetts Avenue N.W., Washington 6, D.C.

Bailey Films, Inc., 6509 De Longpre Avenue, Hollywood 28, California.

Classroom Films Inc., 321 East 44th Street, New York 16, New York.

Coronet Films, Coronet Building, Chicago 1, Illinois.

Educational Services, 1702 K Street N.W., Washington 6, D.C.

Encyclopaedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois.

Eye Cate House, 2716 41st Avenue, Long Island City 1, New York.

Informative Classroom Picture Publishers, 31 Ottawa Avenue N.W., Crand Rapids 2, Michigan.

International Film Bureau, Inc., 57 West Jackson Boulevard, Chicago 4, Illinois.

Life Magazine Filmstrips, 9 Rockefeller Plaza, New York 20, New York.

McGraw-Hill Book Company, Inc., Text-Film Department, 330 West 42nd Street, New York 36, New York.

National Film Board of Canada, 1270 Avenue of the Americas, New York 20, New York.

Popular Science Publishing Co., Audio-Visual Division, 353 Fourth Avenue, New York 10, New York.

Society for Visual Education, Inc., 1345 West Diversey Parkway, Chicago 14, Illinois.

United States Department of Agriculture, Photo Laboratory, 3825 Ceorgia Avenue N.W., Washington, D.C.

United World Films, Inc., 1445 Park Avenue, New York 29, New York.

University of Michigan, Audio-Visual Education Center, Ann Arbor, Michigan.

Young America Films, Inc., 18 East 41st Street, New York 17, New York.

Slide producers:

American Museum of Natural History, Slide Division, Central Park West at 79th Street, New York 24, New York.

Carolina Biological Supply Company, Elon College, North Carolina.

Central Scientific Company, 1700 Irving Park Road, Chicago 13, Illinois.

General Biological Supply House, 8200 South Hoyne Avenue, Chicago 20, Illinois.

Society for Visual Education, Inc., 1345 West Diversey Parkway, Chicago 14, Illinois.

Visual Sciences, Box 599, Suffern, New York.

Ward's Natural Science Establishment, Inc., 3000 Ridge Road East, Rochester 9, New York.

PROFESSIONAL ORGANIZATIONS AND PERIODICALS

In the long run, books, films, filmstrips, slides, pictures, and all the other materials are supplementary tools. The basic factor in teaching is the teacher himself. He needs ideas and information. He needs to know tried and proven techniques. An effective teacher never teaches the same thing twice in the same way. He constantly changes his techniques both because he is improving on what he has done before and because he is fitting his instruction to the particular group with which he is working at the moment.

But this kind of continuous evaluation and change requires that the teacher have sources from which he can draw ideas. A major source of ideas is one's immediate colleagues. Teachers of long experience have much to offer a young person just entering the profession. There always should be a sharing of knowledge and ideas among the staff members of a school. This kind of sharing also takes place on a nationwide basis. There are two major science education organizations in the country which carry on this work.

THE NATIONAL SCIENCE TEACHERS ASSOCIATION,
1201 16th Street N.W.,
Washington 6, D.C.

This organization is an affiliate of the National Education Association. It has a special interest in elementary school science and publishes both a monthly journal, *The Science Teacher*, and a supplement, *The Elementary School Science Bulletin*, which appears several times a year. Both of these contain articles which discuss a wide range of ideas and experiences for classroom use. In addition to these publications, the N.S.T.A. organizes workshops in science education, and conferences and conventions which devote much time to elementary school science problems. Moreover, the N.S.T.A. packet service brings members large amounts of free materials on all kinds of science topics.

COUNCIL FOR ELEMENTARY SCIENCE INTERNATIONAL,
John McLain, Secretary-Treasurer, Supervisor of Elementary Education, South Milwaukee Public Schools, South Milwaukee, Wisconsin.

This group devotes its attention exclusively to elementary science problems. Its ideas and contributions are published in *Science Education*. The meetings of the Council give attention to science curricula, science problems, science ideas, and science teaching materials for the kindergarten through the sixth grade.

Of course, the general state and national teachers' organizations such as The National Education Association, The Association for Childhood Education, International, and The Association for Supervision and Curriculum Development, and regional organizations such as the School Study Councils give some attention to elementary science problems. Teachers should take advantage of the materials and publications of these organizations.

Besides keeping up with new professional educational developments, the teacher should know what is going on in the world of science. By reading recognized science periodicals and current

newspapers and weeklies, the teacher can keep abreast of the recent happenings in science. The following is a list of suggested science periodicals.

Junior Natural History. American Museum of Natural History, Central Park West at 79th Street, New York 24, New York.

Natural History incorporating *Nature Magazine*. American Museum of Natural History, Central Park West at 79th Street, New York 24, New York.

Audubon Magazine. National Association of Audubon Societies, 1130 Fifth Avenue, New York 28, New York.

Cornell Science Leaflets. New York State College of Agriculture, Ithaca, New York.

Science News Letter. Science Service, 1719 N Street N.W., Washington 6, D.C.

Scientific American. Scientific American, Inc., 415 Madison Avenue, New York 17, New York.

This is science education: the children, the teacher, the ideas, the equipment.

XIV INTEGRATING SCIENCE WITH OTHER AREAS

FROM Phoenix, Arizona, to Salt Lake City, Utah, is a distance of only 504 miles by air. In a modern, commercial airliner, that is a flight of less than two hours. Yet traveling from Phoenix to Salt Lake City can take you from a temperature of well up in the seventies to a temperature of zero or below. And you can go from no snow, or just a trace of it, to storms of blizzard proportions. Year after year there is only a trace of snow at Phoenix, while the annual snowfall for Salt Lake City runs to about fifty inches. Or take the situation in a place like Dallas, Texas. The temperature there can range from as low as two or three degrees below zero in January to a temperature of one hundred ten degrees in July. This is quite a range. Rainfall and total annual precipitation are other interesting phenomena. In a place like Bakersfield, California, the total rainfall for a year is likely to be less than seven inches. Yet San Francisco which is only 250 miles away, will have more than twenty inches of rain. How can these facts be explained? And, furthermore, how do they affect people?

How does it happen that Bakersfield, with its very small annual rainfall, is in the center of a major agricultural area, while other places with much more rain support very little agriculture and have practically no crops?

These are the kinds of science questions which adults are most likely to ask themselves. It is a rare person who either needs to know or wants to find out the characteristics and prevalence of cyclonic patterns for an area. And the adiabatic characteristics of air masses may be of concern to a climatologist, but they are not at all the kind of common information which men need and use day after day as they search for an understanding of their environment. When a man is going to take out his dinghy, or when he is going fishing, or when be is going to play golf, he just wants the answers to two simple questions: Will it be safe? Will it be pleasant? And when a women is concerned about the weather it is more likely to be in terms of the hat she should wear, or whether she should try drying the clothes outside. She wants to know the same kinds of things: will it be comfortable? Can I get my work finished? Or, if they are at all concerned with the nation-wide weather conditions, it will be in terms of the effect of such conditions on their food supply and cost, or in terms of the effect on their travel, or the effect on their water supply.

In other words, in the common range of experiences men are concerned with science as it affects their lives. People operate as total beings, not as disembodied minds. Their problems do not stay within arbitrary boundaries which have been established by academic curricula. Rather, men attack a problem and seek, from whatever disciplines available, those resources and that information, which they need in order to solve their problem. As they strive toward their goals, as they continue to grow, they seek ways of increasing their personal integration and they seek to understand and fit into their environment. The educated man is the man who can bring to bear on his problems that information

and those skills which will enable him to find satisfactory solutions. This is a major goal of education.

THE SCIENCE ASPECTS OF MODERN PROBLEMS

Even though teachers should continue to devote considerable time to the individual subject areas, they need to find ways to introduce units of an integrated nature and use them to help children with problem solving. In the introduction of this book it was pointed out that: "Most contemporary problems with which the citizen is concerned are interwoven with science." Whether the problem is a personal one or a social one, whether it is the problem of a child or of an adult, it is likely to have aspects which can be clarified by an understanding of science concepts. But the problem usually does not fit any single traditional subject area. Nor, for that matter, are the solutions to such problems solely dependent on science information. Rather, all kinds of concepts from all of the discipline areas must play a part in the solutions, and science plays a major role. Furthermore, fundamental to the point of view of this book is the thesis that science materials, in particular, lend themselves to integrated study units. Science affords factual materials and concepts which are useful in the solution of the problems involved, and provides the students with opportunities to learn and use rational techniques necessary to problem solving. A program of such integrated units, when soundly employed as one part of the elementary school curriculum, can lead to more effective learning.

First, there must be a problem. It must be whole and it must be presented to the children as a whole. Next, its ramifications must be allowed to lead where they will, crossing subject matter lines when necessary. If the problem needs to call on concepts from the social sciences for part of its solution, then the children

must he helped to acquire those concepts. And if science information is needed in dealing with a social science topic, then it must he forthcoming. Integration does not mean merely the integration of two or three subject areas hy hringing them into the same classroom to be taught together. That kind of integration is superficial, if not false. Rather, the integration must be through the problem itself. Thus, materials which are commonly thought of as helonging exclusively to separate and distinct academic disciplines can be brought into a unified whole for the solution of the prohlems at hand.

STATING THE PROBLEM

The first and most important step is stating the prohlem. No matter how large the problem or how small, it must be looked at as a whole. It must he stated so that its ramifications, its implications, and its varied phases can he seen. True, the young and inexperienced student will not be able to see deeply into the problem. Therefore, it is the responsihility of the teacher to make certain that the students are aware of the varied ramifications. Every prohlem that is considered, whether it he the hase of an integrated or "core" unit, or a unit which will concentrate on some special information in science, social science, or language, must he seen both hy the children and hy the teacher in a hroad perspective, thus allowing the students to examine the problem as it exists in real life.

In the intermediate grades an example of such a problem is the very important study of the United States. Often, the study of American history, the study of American geography, the study of American democratic procedures (Citizenship Education) are presented independently of one another. However, it is more likely that these three topics are woven into an integrated whole.

But that is hardly enough. Nor is it enough to study the social sciences as an integrated whole and then, because the children are studying the geography of America, to study weather and climatology at another time during the same school day or days. The whole problem of America as a place to live needs to be studied and understood in a unified way if the integration is to be successful. Suppose the children are to study the southwestern United States. The problem could be amplified as follows:

New Mexico and Arizona are desert states with mountains of very great height. What are the natural conditions that people have to deal with in these states? How can these conditions be modified? What effect did these conditions have on the history of these states? How do the people make their living because of the fact that their land is mainly desert and mountainous?

The answers to these questions will necessitate a meaningful integration of science and social science. And not only will both of these broad areas of subject matter need to be brought into play to answer the questions, but this very kind of study will lead to all kinds of new and interesting problems with which the children can work.

There are dozens of such problems which lend themselves to this kind of integrated study. Here are a few of them:

1. In a democracy, news needs to be brought to the people quickly and accurately. How is this done in America? What are the ways in which news is gathered and reported? What are the machines for collecting and printing news and how do they work? How is the news gathered in our home town and how is it spread? How was the news gathered when America was a British colony? What is a free press? What is the newspaper's responsibility to the public and to the government?

2. One thing that all men need is water. In the United States today, for every man, woman, and child about 125 gallons of water are used each day. That is fine if one lives where such a supply is easily available. But most of us live in cities and towns crowded close together and without enough water in or near the city to provide for our needs. For example, each year New York City needs about 1.5 billion gallons of water. But even using all of the wells and all of the fresh water supplies from all of the surrounding area would not give the people of New York a fraction of the water which they need. How can a big city like New York get the water it needs? How can water be carried the long distances which are necessary to get it to a city? How can water be purified at all and how can it be purified in the large amounts needed for a big city? Once such a large amount of water is brought into a city, how can it be gotten rid of? How are such services provided for people? Who pays for the services, and how much do they pay for them?

3. Not so very long ago, people in America used to eat food that was grown or raised within a few miles of the place where they lived. Except for sugar, tea, a few spices such as pepper or cinnamon, and a few fruits which came as very special treats on holiday occasions, the bread, the meat, the vegetables, and all the other foods which came to America's tables traveled no more than from the neighboring farm to the grocer, and then to the table. But meals today are quite different. At breakfast there is coffee from Central or South America and bananas from the same area. The wheat in the cereal might come from the Dakotas while the bacon might come from Kansas and the cocoa from Ghana. Lunch and dinner would present the same picture. Fruit in winter could come all the way from South Africa. Meat could come from anywhere in the world—possibly from Texas, or from Wisconsin, or from Pennsylvania, but it could come from Argentina, or New Zealand, or from Australia, or Canada. The vegetables could come from a neighboring farm, and

so they would when the harvest season was right; but they could also come from places as far away as across the continent or from South America. How have we managed to bring this variety and this plenty to our tables? How have men solved the problems of food preservation that have plagued them since the dawn of civilization? How are foods transported? How has food supply affected politics and international relations?

4. *As recently as fifty years ago, a trip of even fifty miles was a major undertaking. True, some people did pull up stakes and head off to America, or if they lived in America, they might gather up their belongings and head for the west.* But once they got where they were going, most of them settled down and stayed put. How different it is today! Most children who are alive today have traveled more in the few years they have been alive than their great-grandparents did in the course of their entire lives. What are the machines man uses in travel and how do they operate? How do they differ from machines used in former times? What are the sources of power that man uses in order to travel? What does he need to know to go from one place to the other? How have modern methods of transportation affected our relations with the rest of the world?

5. *An orchestra, as it plays music, makes many different sounds. When one listens carefully, he hears each of the instruments.* It becomes clear that each instrument has a different quality and each is unique. Each, however, has a part in making the whole or total musical story. How are these different sounds produced? How are the three types of musical instruments (strings, winds, and percussions) different and how are they alike? How are the instruments in any one group, the wind instruments, for example, the same and how are they different? What makes a sound musical and what makes it noise? How are sounds related to one another? Why does music from India or from China sound different from American or European music? How

can we make musical instruments produce the sounds we want to hear? What do you do to "tune" an instrument? How do musical instruments work?

These are all examples of big, broad problems that lend themselves to integrated study. The questions that grow from each of the topics can be extended and multiplied and can lead off in many directions. Each has many sub-topics. And each of the sub-topics can benefit from an integrated approach. Consider, for example, a related problem growing out of the study of "Community Helpers." Such a unit is often done in a second grade. Mostly, teachers have worked with "helpers" like the policeman, and the fireman, and the postman. But there are many more "community helpers" who can and should be studied. There is the doctor, and there is the grocery man, and the shoemaker, and the garage man, and the baker.

A STUDY OF BREAD IN THE SECOND GRADE

In a second grade, the problem would be kept at a simple level. None the less, it would be an integrated problem and the teacher would help the children draw materials from many of the discipline areas. First, there must be a statement of the problem.

Here is one way in which this could be done:

There is a very important man who lives in our town. He makes something which all of us use every day. He makes bread, and he also makes other good things to eat. What are all the different things which the baker makes? How does he make bread? What does he put into the dough to make cake, cookies, pies? Do any people beside the baker help him make the baked goods? How does the baker take care of the baked goods before he sells them?

Generally speaking, this kind of unit occupies only a small part of the class day, perhaps twenty-five or thirty minutes, except on those days when some special activity such as a visit to the bakery or the baking of bread or rolls in school is planned; and it can extend over a period of several weeks. Such a unit takes up whatever material is needed to answer the questions raised. For example, the children need to spend time finding out about the people who are involved in the bread-making process. This would include finding information about the raising of the necessary ingredients, about the preparation of the wheat, about how the materials are brought to the bakery, and about the buying and selling connected with a bakery shop. These areas each have many implications which can be explored by the children and the teacher. The children will read about bread and bread making. They themselves will bake bread. They will write stories about the people who help make the bread. They will collect pictures of these people and use them to illustrate their experience charts. They will draw pictures for their stories. In short, their experiences will range over the whole of the curriculum. Here are some of the topics which a second grade might study, with each of them placed where it seems to fit in connection with the common subject matter areas:

I. *In the area of social studies*

1. Finding out where the flour that is used in baking comes from
2. Finding out about the other ingredients that are used in baking
3. Finding out the occupations of the various people who actually have a part in producing bakery goods

II. *In the area of health*

1. Finding out why bread is wrapped
2. Finding out why cake is kept in a glass case

III. *In the area of arithmetic*

1. Finding out about the costs of bakery products
2. Finding out the meaning of "dozen," "half dozen," etc.

IV. *In the area of language arts*

1. Reading and writing stories about bread and bread making
2. Reading and writing recipes
3. Learning new words

V. *In the area of science*

1. Finding out what yeast does to dough
2. Finding out the effect of baking soda on dough
3. Finding out about some of the machinery needed in baking
4. Finding out some of the basic concepts involved in the relationships between time, temperature, and baking

The teacher is well aware of the importance of making the study thorough, but none the less at the level which the children can understand. For this reason, the teacher will choose only a few basic concepts and will stress them. In this case, one concept will be:

To make dough into bread, it is necessary to mix bubbles of a gas into the dough.

This can be done by using yeast, or baking soda and water, or by beating air into the dough, or by using a combination of all three methods. Thus, when the dough is baked, it will become soft, and spongy, and tasty. The teacher limits this basic concept and does not consider material about the nature of yeast, nor about the chemical reaction of baking soda and water, nor about the physical principles involved in beating air into dough. Such materials are too advanced for second grade. The teacher emphasizes the simpler concepts and fixes them in the children's minds.

A STUDY OF BREAD IN THE SIXTH GRADE

Obviously, there is much more to be gained from the study of bread and bread products and from a study of the science involved in their production. An upper elementary grade, working on a study of "My Body and How It Works," again can study the making of bread in an integrated unit. Their work will be much wider in scope and deeper in understanding. The statement of the problem will reflect this. Here is the problem as it might be stated for such a grade:

> Bread is called the staff of life. Almost all people around the world have some kind of breadstuff which is basic to their diets. Some use wheat as their grain, some rice, others rye, still others maize. But, whatever the basic grain or "corn," most people have "bread" which appears at almost every meal. Why is bread so important to the body? What is the meaning of "calorie" when it is used in connection with food? What are some of the different kinds of breadstuffs which are used around the world? What is the difference between "bleached" flour and "whole" flour? What scientific information is used in the making of bread? How is the bread that is in general use today made and how does this compare with the way bread was made in pioneer times?

Answering these kinds of questions requires much more maturity than did answering those which were posed to second grade children. But the new learning can be built upon the rounded picture which the second graders took with them after their study of bread making. In an upper grade, the subject matter covered in an integrated unit study would have even wider scope than that done at the second grade level. Here, for example, are some of the learnings that might be carried on as they appear in subject matter divisions:

I. *In the area of social studies*

1. Finding out about the use of bread in the local community
2. Finding out about the role of bread in the history of civilization
3. Finding out about the different kinds of bread and about the meaning of the word "corn"
4. Finding out how bread is produced commercially and how bread was produced in pioneer times
5. Finding out bow bread is made in a small bakery as compared with a large factory operation

II. *In the area of health*

1. Finding out about the role of starch and carbohydrates in nutrition
2. Finding out why vitamins are added to flour
3. Finding out about the role of sweets in diets
4. Finding out about public health laws including the Pure Food and Drug Act and their effect on the operation of a bakery
5. Finding out about the health import of breads made from different kinds of grains
6. Finding out the facts about bread "softeners"

III. *In the area of mathematics*

1. Finding out about the weights and measures used in the production of bread
2. Finding out about the total annual amounts spent by a family on bread and bread products
3. Finding out about the total annual amounts spent nationally on bread and bread products

IV. *In the area of language arts*

1. Reference work
2. Written and oral reports
3. New vocabulary
4. Interviewing bakery workers

V. *In the area of science*

1. Finding out about yeast as a plant
2. Finding the nature of the yeast reaction including the elementary chemistry of the carbon dioxide-oxygen cycle
3. Finding the nature of the chemical reaction of sodium bicarbonate and water or acid
4. Studying chemical reactions of baking and cooking
5. Finding the physical principles involved in mixing gases into dough

Here are some of the activities which have special science emphasis:

1. The class can obtain commercial yeast and examine it with the aid of a hand lens.

2. Each child can grow yeast under a variety of conditions: in sugar water, in molasses, in potato water, etc.

3. Each child can prepare yeast doughs and can do quantitative experiments on such things as amounts of yeast used and resultant conditions of dough or on the relative effects of different temperatures on yeast gas yield.

4. The children can experiment with making root beer using sugar water, yeast, and syrup. There are a variety of tests to be made: the effect of eliminating one of the three ingredients; the effect of using boiling water; the effect of placing the mixture in the refrigerator while or before it has produced gas; the effect of using ice water in the mixture. Other variations can be devised by the children.

5. The children can carry on simple fermentation experiments using fermentation tubes, and they can test the resultant gas and learn the nature of carbon dioxide.

An analysis of these activities indicates that they draw on information from physics, chemistry, and biology. It is important,

however, that the teacher again choose carefully the basic concepts that he is going to stress. At this upper level there will be a greater number of concepts, each of them will be more complex, and there will be enough range in their complexity so that the much wider interest and ability span of the upper graders is satisfied. Here are some of the science concepts which could be stressed at this level:

1. Yeast is a living plant of the fungus variety.

2. Yeast reacts with carbohydrates to form carbon dioxide and alcohol.

3. Fermentation is a natural process which has been used by men both for bread making and for making alcoholic beverages through the ages.

4. The conditions under which the yeast reaction will occur are limited by time, temperature, and quantity.

The kinds of lessons that can be carried on with this sort of material are also interesting and unique. The teacher can start a class with materials like: soda crackers, unleavened bread (matzoths), or hardtack, corn pone, or hoe cake; the raw ingredients for one of these items, as well as some yeast and some baking soda (sodium bicarbonate); and the necessary baking utensils, including a good electric or hand beater. With these, he can help the children make a thorough study of the effect of various leavens and leavening methods on dough. It is not enough to stop here. The reasons why these leavens work, the measurements involved in making them work at optimum levels, the historic import of leavens, all of these will make important additional lessons. But such information as the chemical formulae for various carbohydrates and for the alcohols produced in the fermentation process will be beyond the range of many of the children and will be the work of only a special group who have particular interest and ability in this area of science.

In like manner, some of the children will have special interest in some of the social and historical concepts and information. Thus, the one, big, integrated problem will be the base for many different kinds of important school activities:

1. The group as a whole will work on understanding a problem as it actually exists for men—not in artificial compartments, but in closely interrelated areas from various disciplines.

2. The group will gain a variety of skills and information.

3. Individuals will have a chance to see problems as wholes, each to the extent that he is able to see the whole.

4. Individuals with varying interests and abilities will find materials and ideas which they will be able to explore so that they can both contribute to the class's understanding of the problem and further their own interests.

The integrated units which have been described so far are of the kind which can and should be planned long in advance of their use. In fact, units of this kind need to be placed in the program of any class only after they have been seen both in relation to the rest of the class curriculum and in relation to the over-all school curriculum. Integrated units too must have a continuity and must follow the criteria which were established for planning the school program. They will be simple and concrete in the lower grades; they will be more abstract in the upper grades. They will correspond to the children's interests in so far as possible. They will be built upon the needs and demands of society.

INTEGRATING SCIENCE WITH CURRENT EVENTS

There is, however, another phase of the curriculum where the integrated learning situation is inherent; namely, current events.

Consider these headlines in *The New York Times* in the course of a single week:

"U.N. Atom Panel Agrees Fall-Out Is Peril To Man"

"Khrushchev Urges More Steam Power"

"Nautilus Sails Under The Pole And 1830 Miles Of Arctic Ice-cap In Pacific-To-Atlantic Passage"

"Glennon, Ohio Educator, Named To Direct U.S. Space Unit"

"Top-Shaped Device To Be Shot At Moon"

"Eisenhower Signs A.E.C. Funds Bill"

Undoubtedy this material belongs in the school. Even if a teacher wanted to bar it from the school program, he would have to battle against the interests of the children. Imagine a sixth grade that had no discussion of the voyage of the Nautilus or the successes and failures of satellites and of rockets to the moon! Furthermore, the teacher should do more than just allow it to come into the classroom, the teacher should make definite plans for current events to be considered.

Young children are not likely to be aware of too many of the daily news items. Only the most dramatic items will come to school with them. Even the very young ones, however, will be concerned with the spectacular news as it occurs. The first grades of the country buzzed quite as much when "Sputnik I" hit the sky as did the sixth grades, or tenth grades, or college classes. When these young children are concerned with such a current event, the teachers need to help them understand it at their stage of development. This means, for the most part, helping the children understand "what it is" rather than "how it works." Little children need to know that:

A satellite is like a moon. It is a small, hollow ball made out of metal. Men have shot it up into the sky. Now it is circling

around the earth. It is so small that we cannot see it the way we see the moon. But scientists who have telescopes and who know when and where to look in the sky can see it. It looks like the moon too, only it is much smaller and moves very fast as it travels across the sky. It cannot harm us. It was shot into the air to gather information. Its radio sends this information back to the scientists.

What young children need most is to understand what is happening and thus to fit it into their concepts of the universe.

Generally, however, the young children are much more concerned with the immediate and local happenings of their world. In a sense, these are their news items, and when science concepts are related to the events which these young people bring in, they should be considered. The following are samples of such items:

"It hailed so hard last night that the hailstones broke a window in our car."

"We had no electricity in our part of town for two hours yesterday. We had no lights, and we could not cook, and the television set was off too, but the telephone was working."

"Our whole lawn was covered with grasshoppers this morning."

"The snow was so high in front of our house this morning that we could hardly get our car out of the driveway. But there was no snow on the sidewalk across the street."

This kind of item will certainly come to the attention of each teacher and he must be alert to each as it comes up and help the children find some of its varied implications.

As the children move into the intermediate and upper grades, they can understand the meaning of current events more easily

and they enjoy studying them. Regular periods devoted to the study of man's contemporary problems and their implications are, therefore, necessarily part of the elementary school program. In these grades, the implications of the science news items, such as those that were listed, need to be fully developed. The discussion by an upper grade of the first news story listed above might include the following:

> Atomic fall-out is an issue which must be resolved in the next few years. There is no doubt that radiant energy in large doses has a bad effect on living tissue. But the question is much more complex than simply stopping the testing and use of atomic weapons. First of all, it must be noted that dangers to mankind are seldom absolute. The question becomes: Is it more dangerous for us to continue to test atomic weapons and risk injuring men through these tests, or to stop the tests and risk having our possible enemies become relatively more powerful because we have stopped them? But when that issue is resolved, there is still another matter to be considered. Even if all testing of weapons should be stopped, the radiation danger will not be eliminated because, unless men decide to go back to the pre-atomic age—and that cannot happen—much radioactive material will be released into the atmosphere through the peacetime use of the atom. Thus, the question now becomes: How can radioactive materials be kept from the atmosphere, or how can living things be protected from the ill effects of radioactive materials?

Any of the headlines could be analyzed in a similar way. For example, a story as spectacular as that of the Nautilus is bound to reach the classroom. What the teacher does it to help the children examine the various implications.

> Does this journey mean a new ocean travel route for carrying cargo and passengers? Will the route be useful year round or only for small parts of each year? What does this

voyage mean in military matters? Are there any natural resources such as oil in the arctic areas? Can the resources of the Arctic be tapped by the use of submarines?

These kinds of news items can be used to expand the vision of the elementary school children. It was Jules Verne who first had a submarine sailing under a polar icecap. And space travel and rockets to the moon were, just a few short years ago, the sole province of science fiction authors. But these feats are no longer in the realm of fiction. Here are headlines that in a matter of fact way report the establishment of a government space agency, and a rocket shot to the moon, and a trip under the polar ice. Children of today certainly will not live the way we have lived in the past. They will travel farther and faster and more often and to more strange places than we have ever imagined. People will have many new decisions to make because of the space age.

The teacher's role in bringing about sound decisions is clear. He must help the children see the ramifications of the problems. He must help them widen their views. But, first, he must widen his own views. He needs to look at each of the current events items carefully and find out the many areas to which it leads and from which it comes. As was said before, the business of the world is the curriculum of the school. The teacher first tries to understand the business himself; then, he helps the children understand it too.

Summary

Since problems that men face are integrated, it is the rare instance in which men need to call on information from only one discipline to solve their problems. This means that the school needs to set up as many problem situations as possible in which children have to use

information from all of the academic disciplines. During the entire school day and through the entire school year this should be the case. Whenever a teacher introduces a new problem, whether it be in the social science class, the English class, or the science class, he must help the children see it as an integrated problem. But, in addition to this approach, the teacher can bring special integrated units to the classroom through the use of the kinds of problems that have been described in this chapter.

The problems that are chosen can fit into an over-all school plan for such integrated units, but they can also be introduced by the individual teachers whenever they seem appropriate to the work of the class. The first thing that the teacher needs to do is to think through the statement of the problem. The statement of the problem is an essential part of planning. By preparing the problem carefully, the teacher not only is able to present it to the children more adequately, but he is also able to introduce its various ramifications and implications. This is essential if problems are to be considered in a thorough way and superficiality avoided. The teacher employs the basic learning principle: Learning is often facilitated when the learner sees a whole or unified problem and sees the significance of its related parts.

The Gestalt approach—the approach to teaching and learning upon which this integrated program is based—has at times been misinterpreted to mean that subject matter and substance can be eliminated from the program. "Just teach the children to think," some have said. But this is obvious nonsense. People cannot think in a vacuum. There are few problems that children can solve if they have no science concepts, nor history information, nor mathematics generalizations with which to attack them. But the authors contend that, given a well-rounded picture of the problem, and given the opportunity to search out applicable materials for its solution, children are more likely to do a more thorough job of both solving the problem and of finding information in the subject matter areas than they would with no such integrated approach.

The children must be led to search in the sciences and the other

discipline areas for the generalizations which they can use to solve their problems. And, moreover, they should be encouraged to dig deeply and thoroughly into the various phases of the problems which they consider. A superficial examination of a problem is worse than no examination at all. For this reason, it seems wise to limit the number of problems that any class examines and to allow sufficient time for each problem so that it can be given as thorough consideration as the maturity of the students warrants. It is better to do fewer such units during a school year and do them thoroughly than to try to cover many and do them superficially.

Once the teacher has examined the problem himself and set it up, he can help the children tackle it. Children of differing interests and abilities have a chance to specialize in those phases of the problem which are of special interest to them. Each child is helped to understand the full and rounded problem to the extent which he is able. And, finally, the whole class contributes to the solution of the problem and each child then can take away an answer which is personally satisfactory to him.

What can this kind of program do? First, of course, it can encourage the children to find information. They can delve into a multitude of areas. Second, it can help the children learn some of the techniques of problem examination and problem solving which they must use in their daily lives and which they will continue to use as adults. But, most of all, it can help the children see a relationship between what is learned in school and what exists in the world outside of school. This is most significant. When children can see the interdependence of the school curriculum and the world at large, they not only want to learn, but they do learn. Integrated units serve these purposes.

CONCLUSION

The incredible pace at which science has progressed during the last century has completely changed our way of living. It took one hundred years for railroads to become the backbone of America's transportation system. It took only fifty years for

the automobile to become an integral part of our lives. But the airplane came into its own within twenty-five years. And in every other area of our civilization, science and technology are taking similar giant strides and going ahead at an ever increasing rate. Today's child needs to know much more science than his father. He even has to know more than his older brother. Where else can he begin to learn this science but in his elementary school?

As the need for more and more science has become clear, schools are organizing and will continue to organize a variety of programs in the science area. Such experimentation is always helpful, but regardless of the kinds of frameworks that are designed, the principles outlined in this book—for the establishment of objectives, for the selection of content, for the techniques of teaching, for the methods of evaluation—in short, for the development of a total elementary school science program can serve as a useful and valuable guide for teachers and administrators.

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